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The effect of age distribution and female culling on the profitability of the dairy herd

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The effect of age distribution and female culling
on the profitability of the dairy herd

by

Ronald Earl Pearson

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INTRODUCTION

Much work has been done establishing genetic and economic parameters of the dairy operation, and many separate predictions have been made using these estimates. However, the complete economic evaluation of dairy cattle breeding programs has seldom been attempted.

Several factors have been shown to exert major influence on the relative genetic, phenotypic, and economic levels of a dairy herd under different selection programs and on the rates of change caused by different selection systems. These include:

1. Only a small percent of the total genetic gain made is accomplished through female selection. (Robertson and Rendel, 1950)
2. Production increases at a decreasing rate to maturity and then decreases slowly as age increases. (Lush and Shrode, 1950)
3. Limitations on selection are established by the number of females born, the percent that survive to first freshening, and the percent lost to involuntary culling at each age during their productive life. (Meadows, 1968)
4. Calf losses increase with increasing herd size, but decrease with increasing production. (Meadows, 1968; Johnson and Harpestad, 1970)
5. Cow depreciation is a major cost component of milk production. (Becker, Arnold, and Spurlock, 1954)

Given these concepts, the question of the most profitable age distribution of a herd, or more specifically, the type of culling that would produce the most profitable herd is still unanswered. This is the main question that will be studied in this work.

In dairy cattle unlike most other species, a single trait, milk production, has overwhelming economic importance. While this picture is clouded by the way milk is priced and by the negative genetic correlation between milk yield and milk fat percent, milk is clearly the most important economic trait on which animals should be selected. Such secondary traits as milk fat percentage, total solids percentage, type score, ease of milking, temperament, and reproductive efficiency have some economic importance in certain situations. Several of these traits are lowly heritable or are not easily measured in an objective way, and several have little or no economic importance in commercial dairy operations. Thus, the amount of economic gain that could be made if they were included in the selection program is reduced. This has led many dairy scientists to place the majority of their selection emphasis on milk production.

The usual approach to maximizing economic improvement, from a genetic viewpoint, has been to use the selection index approach suggested by Hazel (1943). This system takes into account the genetic and phenotypic relationship between the traits on which selection is practiced and the relative economic value for each trait. However, this approach does not easily adapt to the comparison between systems with varying amounts of fixed costs associated with animals of different ages. Nor does the index approach give economic credit for improvement in permanent environmental and non-additive genetic effects, while these improvements may increase the present profitability of the herd. This extension would only be necessary when the expression of the trait continues past the time of selection, as in the case of milk production in dairy cattle. Also, in dairy cattle, the use of

Mature-Equivalent (ME) production has been a valuable tool in making genetic progress, but acts as a confusing factor in making economic decisions. Thus, in judging selection practices based on profitability, use of the selection index approach is not sufficient in itself. Part of the purpose of this study will be to develop a deterministic simulation procedure to provide the extensions mentioned above. This type of approach is in no way a substitution for the selection index approach, but rather an extension of the approach to help make decisions between selection systems.

Deterministic models will be used to simulate the genetic and actual production levels over time. The physical characteristics, other than milk production, will be chosen to fit each herd-size, production level and selection system based on estimates from the literature and on general knowledge of the dairy operation. Each time period will be evaluated at all combinations of the different levels of milk price, feed price, and rearing cost. These economic levels will be chosen to encompass the majority of the prices experienced by midwestern dairymen.

Four cow selection systems will be combined with three sire schemes to simulate the genetic and phenotypic levels for herds of different sizes producing at three levels of milk production. The results from each herd will be evaluated economically as described earlier. The purpose of including the levels of the economic, physical, and genetic factors in addition to the cow selection schemes was two fold: first, to provide a choice of levels that will fit individual dairymen in the Midwest; second, to evaluate the influence of changes in the economic and physical parameters on the relative ranking of the four cow selection systems over time. The results of this simulation study will be discussed in relation to the major forces influencing increased profit.

REVIEW OF LITERATURE

The review of literature for this study will be considered in several subclassifications: total economic evaluation of selection systems, general considerations of estimating (predicting) genetic gain, cow selection, sire selection, estimates of heritability and repeatability, age distributions and herd-life expectations, and physical inputs and economic cost relationships for the dairy herd. The approach to this section will be intentionally general, with an effort to supply only enough detail to support the work presented in the Procedure section and to orient the reader to the basis of the approach used in this study. This section is also intended to express the appreciation of the author for the work that has been completed in these areas of animal production without which this study would not be possible.

Total Economic Evaluation of Selection Systems

Several attempts have been made to provide a total economic evaluation of selection programs. Strain (1961) in 1961 analyzed random sample broiler operations. He also evaluated the importance of the rate of egg production and adult body weight in integrated and non-integrated operations from the profit equations developed.

Swanson (1965) in 1965 developed profit equations for sheep enterprises. He also calculated the effect of changes in profit potential for two types of sheep operations, farm-flock enterprises, and feeder-lamb range enterprises, as production changed. The approach that was used by Swanson was quite similar to one used previously by Strain.

Smith (1964), and Moav and Moav (1966) showed that any expression of profitability of the crossbred must be a function of the reproductive performance of the parents and productive efficiency and quality of their offspring. In a series of four papers in Animal Production (Moav, 1966a; Moav, 1966b; Moav, 1966c; and Moav and Hill, 1966), Moav, and Moav and Hill explored the economic considerations in developing specialized sire and dam lines. Moav (1966a) developed a general expression for the profitability of the crossbreds. This expression for net profit included gross income, production cost, and reproduction cost. He further showed how the genotype of the sire, dam, and crossbred offspring affected the components of the profit expression. With different numbers of males and females needed, the contributions of the parent lines to profit were unequal. He suggested that exploitation of this difference may produce "profit heterosis" even when the component traits are genetically additive. In the three remaining papers, Moav (1966b), Moav (1966c), and Moav and Hill (1966) investigated this situation under different genetic conditions. They also drew conclusions about the most profitable choices of parental lines for each case.

Touchberry (1970) used an economic analysis of the Holstein and Guernsey crossbreeding project conducted at the Illinois Agricultural Experiment Station to demonstrate the importance of heterosis of such traits as viability, growth, and production. He emphasized that the increase in viability both increased income and increased the possibility for culling. From the genetic point of view, the increase in culling possibilities would be a major factor in increasing genetic gain.

General Considerations of Estimating (Predicting) Genetic Gain

Lush (1954) described the factors which influence the rate of genetic change for the situation of no epistasis or overdominance. He presented the genetic change as the product of three factors: intensity, accuracy, and the genetic standard deviation. In the discussion of each of the three factors, he described the ramifications and simplifications that can occur under different selection situations. While he mentioned that the mean length of life, interval between generations, age at first reproduction, and interval between births influenced the rate of genetic progress, he did not include them specifically in the formula he gave.

Lerner and Hazel (1947) analyzed data from a poultry selection project at the University of California. The data they analyzed were collected from 1933 to 1944 from a flock of from 400 to 700 pullets. The flock was maintained under a semiclosed system of breeding, with emphasis on family and progeny performance. Females of two years old and older were used for selection and breeding. One of the main results derived from their study was the empirical verification of the "currently accepted principles of population genetics." They demonstrated close agreement between the phenotypic increase in egg production in the selected population and the expected gain. They also gave a rather complete discussion of three of the four major forces of genetic change: selection, chance, and migration.

Hazel (1943) in 1943 presented the genetic basis of constructing selection indexes. These indexes included several traits and information on relatives. He defined the aggregate genotype (H) as the sum of the relative economic weights times the genotypic value for each trait to be considered. The relative economic weights reflected the amount of profit obtained by improving the trait one unit. The index (I), the criterion of selection, was composed of the appropriately weighted phenotypic measures on the individual being indexed and/or his relatives. The index weights were calculated by solving the equations formed by maximizing R_{IH}. When selection on the index was practiced, the genetic gain in the aggregate genotype was calculated as $(\bar{i})R_{IH}\ \sigma_H$. This appears to be the first formalized attempt to combine genetic and economic information for each trait in a livestock breeding program. Smith (1936) had developed a similar index designed for the selection of plant lines. Many of the remaining references that will be given in this review make use of the selection index method suggested by Hazel.

Dickerson and Hazel (1944) evaluated the use of the progeny test as a supplement to earlier culling. They presented a formula for calculating genetic gain when two stages of selection had been practiced. This formula included the selection practiced at each stage in each sex, and the average age of animals surviving each culling when their offspring were born. They used the procedure of Cochran (presented later in 1951) for calculating the genetic gain for a second stage of selection. One of the most important contributions of the paper by Dickerson and Hazel was the emphasis of the importance of "adjusting" the genetic gain by the generation interval and demonstration of the need to account for the generation interval in both sexes even if selection was only practiced in one sex. They emphasized that gain in one sex is not independent of the generation interval in the other sex. While the formula they presented did not account for all population structures, it was a major step toward the correct evaluation of genetic gain in the population.

Robertson and Rendel (1950) expanded the concepts of Dickerson and Hazel (1944) to better account for population structure. They originated the terminology bulls to breed cows (I_{BC}), bulls to breed bulls (I_{BB}), cows to breed cows (I_{CC}), and cows to breed bulls (I_{CB}). Their formula for calculating the genetic gain of the population took the same form as the formula of Dickerson and Hazel, with the gain from each of the groupings above replacing the gain in each stage of selection for the two sexes. The corresponding generation intervals were handled in a similar manner. They showed that in a unit of 2000 cows with the optimum breeding structure, the proportion of the total improvement due to each of the four classes was as follows:

$I_{CC} = 6\%$	$I_{BC} = 18\%$
$I_{CB} = 33\%$	$I_{BB} = 43\%$

Many of the comparisons used to estimate the genetic gain under different systems of sire selection have made use of the procedure set forth in this paper.

A third approach to determining the genetic gain was given by Van Vleck (1964). He presented an algorithm involving the genetic levels of the permanent and sampling stud in each year. This algorithm assumed that the selection practiced in the cows was zero and that young bulls were the second calf of their dam. Van Vleck carried his results beyond the calculation of genetic gain by evaluating the average net return per cow per year. This appeared to be an appropriate criterion of evaluating the net worth of different selection programs. He also pointed out the cost to dairymen using bulls in the young sire proving program. This was defined as the net worth of the difference in milk production between the permanent stud and the sampling stud.

Cow Selection

In dairy cattle, selection of females is relatively more straight forward than selection of males because the trait of the greatest economic importance is expressed in the females but not in the males. On the other hand, genetic gain in the males is relatively more exploited than genetic gain in the females because of artificial insemination. Over the past 50 years and even before, many articles, both scientific and popular, have been written extolling the virtues of culling dairy cows at various stages of the cow's life. Lush (1946) in an article in Iowa Farm Science presented a synopsis of this problem in a clear and accurate fashion. He concluded that with a repeatability of about 40 percent it would be best to compromise: cull 10 to 20 percent on the basis of their first lactation, but wait to do further culling until five months into the second lactation. Culling in the later lactations would be based mainly on health or poor progeny. He also pointed out the tendency of dairymen to keep cows at the mature ages because of the increase in actual production with age (until maturity).

In addition to the questions posed by the incomplete repeatability of the milk record, several other problems are evident. Estimates of heritability based only on a specific lactation have varied. In the majority of studies completed, heritability of the first lactation production has tended to be higher than the heritability of later lactations. A review of several of these estimates was given by Molinuevo and Lush (1964). The reasons for this trend in the estimates are many and varied, but are relatively unimportant to the discussion here. This trend would tend to slightly favor culling on first calf production over culling on records of later lactations.

The question of whether to cull on traits other than milk production is one that dairymen often discuss. If profit is the only motive of the dairy operation, this question is easily stated. How does change in this trait affect the economy of the dairy operation? The answer to the question is not as easily proclaimed. In light of the evidence that has been accumulated thus far, it seems that there has been a tendency of dairymen to weight traits other than milk production far more heavily than the economic, phenotypic, and genotypic relationships indicate that they should be weighted. The remainder of this section will be devoted to research which has attempted to assess the amount of culling on milk production that has been practiced.

Robertson (1965) used milk yield records of Friesian and Ayrshire cows in Scotland to examine the influence of parity of dam, on daughter's production. He found the production of daughters from cows of later parity was higher than the production of daughters produced by cows in earlier lactations, thus, indicating that selection of dams had been made. In an earlier sample of data, Robertson found that first lactation production was consistently higher for cows that survived to succeeding lactations. He also showed that a larger percent of daughters thought to be born (assuming 50 percent heifers) to cows in later lactations reached the milking herd. Although these measures lack sophistication, they tended to support the hypothesis that female selection for milk production was carried out and to some extent was successful. They also gave some insight as to the way this selection was exerted.

Allaire and Henderson (1966) investigated the efficiency of phenotypic selection (cows surviving to start another lactation) and realized selection (cows represented by daughters). Four hundred and sixty-four herds in New York that were on test continuously from 1957 to 1962 were included in this study. Allaire and Henderson calculated phenotypic selection differentials, expressed as a deviation from the adjusted herdmate average. These differentials ranged from 135 kg to 109 kg for third and first lactations, respectively. The combined differential for phenotypic and realized selection were 121 kg and 140 kg. Estimates of efficiency of phenotypic selection were 0.43, 0.34, 0.27 and 0.25 for lactations one to four, respectively, with a combined estimate of 0.34 for milk deviated from the adjusted herdmate average.

Lund (1966) used 15 years of data from the North Carolina Institutional Breeding Association herds to evaluate the intensity of female selection that had been practiced. He found selection differentials in terms of ME first calf production of cows leaving the herd before the next lactation to be 230, 300, 120, 110, 50, 30, 180 and 70 pounds for lactations two through nine. The relative contributions of different reasons for culling to the selection differential were also calculated. Low production and dairy purposes were the major contributors to positive selection, accounting for 70.0 and 9.8 percent of the total selection. The average selection efficiency for all nine lactations ranged from 22.7 to 31.5 when compared to what could have been accomplished by selecting the same number by truncation selection for milk production. Lund concluded that 2.9 percent of the total improvement made in these herds resulted from female selection.

Andrus (1968) used three measures of production to quantitate the amount of selection that had been practiced in 15,488 cows on DHI test. The three measures were: the average deviations from herdmates production of terminal and non-terminal records; the average superiority of non-terminal records over terminal records; and the average superiority of non-terminal records over all records. The terminal records averaged 553 pounds below their herdmates, with a range from -312 pounds for lactation eight to -629 pounds for the third lactation. The non-terminal records ranged from 465 to 253 pounds better than their terminal counterparts in the first five lactations. The deviation from herdmates for these non-terminal records dropped to 20 pounds by the sixth lactation and to -698 pounds by the seventh lactation. Similar trends were noted in the fat production records. The average superiority of the non-terminal records over terminal records was 852, 1080, 1093, 1026, 738, 418, -355 pounds for lactations one through seven, respectively. The average superiority over all records was 265, 376, 355, 391, 434, 317, and -326 pounds for lactations one through seven, respectively. The negative values for lactation seven were thought to be due to an increase in involuntary culling.

Sire Selection

Lush and McGilliard (1955) gave a general description of sire proving procedures (estimating breeding values). In this paper, they explored the sources of variation that affect sire proofs. They discussed the possible biases that could influence these proofs and gave fairly detailed descriptions of the effects of possible sources of error on several sire proving methods.

Thomson (1968) presented a review of the usefulness of pedigree information as a predictor of the animal's breeding value. He also reviewed early pedigree studies and the index approach to pedigree analysis.

Van Vleck (1964), Henderson (1964), and Legates (1964) explored the various aspects of a young sire proving program. Henderson (1964) discussed the practical and theoretical limits of accuracy from pedigree selection of bulls to be sampled. He examined the effect of choosing bull dams based on five different indexes, each using different amounts of relative information. Henderson (1964) also presented the empirical results for various selection intensities on these indexes and discussed them briefly. Based on these data, he presented recommendations for producing improvement in milk production.

Many other papers have been written, discussing various aspects of the sire selection process and indicating the direction that it should follow. A further view of this subject can be obtained by observing the changes that have taken place in the commercial AI studs operating in the United States. A third view can be obtained from the observation of changes in the commonly used methods of sire evaluation over time. The remainder of the papers that will be cited here involve the measurement of the genetic gain that is possible through sire selection.

Robertson and Rendel (1950) calculated the amount of gain possible in AI with a progeny testing system. They obtained results for different sizes of population, for different numbers of young bulls tested, and for different portions of the population being bred to young bulls. For the population of 2,000 cows, they showed that the maximum progress was obtained by testing 40 bulls in every three year period. The maximum genetic gain was 1.69 percent of the population mean per year. When the population size was increased to 10,000 cows, the maximum genetic gain increased to 2.05 percent of the mean per year. Description of the methods they used in their calculations was given earlier.

Specht and McGilliard (1960) calculated rates of improvement by progeny testing in dairy herds of various sizes. They showed that in closed herds of less than 100 cows progeny testing was not expected to yield as much progress as selecting young bulls on the basis of their dams' production records. In herds of 100 to 200 cows, progeny testing was slightly more advantageous than selection of bulls solely on their dams' records. They also demonstrated that the real advantage of progeny testing was in use in AI with populations of 10,000 cows or more. With this size of population, genetic gains between 1.7 percent and 2.3 percent of the population mean were obtained dependent upon the young sire sampling system used.

Hunt et al. (1970) calculated expected genetic gain in milk production for different progeny testing systems (all untested cows bred to proven bulls) and for a stud composed of all young sires. Increasing the percent of the population bred to young bulls increased the genetic gain in the population for all progeny group sizes. The maximum gain was approximately 1.9 percent of the Breed Class Average (BCA). Increasing the percent of the population which was milk recorded increased the amount of gain possible for all progeny group sizes and for all percents of the population bred to young bulls. Increasing the annual collection rate of proven sires increased the genetic gain slightly. Use of an all young stud was superior to mating young bulls to 20 percent of the tested cows. It was inferior, however, to breeding 60 or 40 percent of the tested cows to young bulls. This switch probably was due to the added gain from use of tested bulls on the untested cows. When equal emphasis was applied to milk production and another trait, genetic gain for milk was reduced 0.1 to 0.2 BCA.

Thomson (1968) calculated genetic gain for four methods of sire selection: (a) all young sire stud (minimum generation interval); (b) all young sire stud (sires of young sires progeny tested); (c) naturally proven bulls; and (d) AI proven sires with a young sire proving program and different numbers of daughters per young bull. Young bulls were mated to tested and untested cows. Each system was evaluated for several population sizes and for several rate-of-first-services per bull. At all population sizes and number of first services per bull, the three young sire systems were superior to use of naturally proven bulls. Progeny testing (d) was always superior to the all young sire system (a) and was better than the young sire system (b) at low usage rates. The maximum genetic gain, with a large population size and high intensity of selection of the progeny tested bulls, yielded slightly better than two percent of the mean production per year.

Walton (1970) presented data from an AI unit which is currently a part of the dairy industry. He discussed the basic principles and concepts on which the selection program at American Breeders Service (ABS) is based. The remainder of his presentation outlined the selection which had been practiced on the dams and sires of young bulls, the selection practiced on the progeny tested bulls, and the results of these selections. The relationship between sire's predicted difference and son's predicted difference was nearly linear. Similar relationships between the dam's herdmate deviation and the son's predicted difference and between the grandson's predicted difference and the predicted difference of the maternal grandsire did not show the same results. In both cases, sons from dams and grandsires of intermediate (within the range tested) production levels were superior to sons from high or low producing dams and grandsires. Results of the first 113 bulls that completed the progeny test were presented.

Phenotypic and Genetic Parameters of Milk Production

Two main parameters are necessary to describe genetic and phenotypic change in milk production with selection. These two are the phenotypic correlation between different lactations, repeatability, and heritability. Because of the large number of estimates of these parameters, only a very few will be included here. A more complete review of these parameters can be obtained by consulting the references cited.

Heritability

Lush (1949) presented a complete discussion of heritability in the narrow and broad sense, methods of estimating it, pitfalls of interpretation, and the importance of the problems unsolved at the time of the paper. This presentation was complete and was written in clear and understandable style. It would be a good starting point to obtain a clear understanding of the concept.

Several authors (Freeman, 1960; Barker and Robertson, 1966; Johnson and Corley, 1961; Van Vleck and Bradford, 1966; Butcher and Freeman, 1967; and Molinuevo and Lush, 1964) have estimated heritability of milk production for each of the first three lactations. In general, the estimates of heritability for first lactation production were higher than the estimates for the later lactations. These estimates for first-lactation production were generally in the range of 0.25 to 0.35. The reduction in the estimates for later lactations were quite variable and seemed to be quite dependent upon the particular data used.

Van Vleck and Bradford (1966) estimated heritability of first-lactation production expressed as 305-day ME production and as deviations from herdmates, from paternal half-sib analysis and from the regression of daughter on dam. The estimates from the two methods on ME production were quite comparable. However, the daughter dam regression produced estimates considerably higher than the paternal half-sib analysis with deviated records.

Several authors have calculated estimates of heritability at different levels of production (Mason and Robertson, 1956; Legates, 1962; and Burnside and Rennie, 1961). The resulting estimates of heritability were extremely variable and appeared to be specific for the individual populations. The one point made by most authors working in this area was that any differences between production levels appeared to be scale differences and not true interactions. Thus, animals tested at one level would tend to rank similarly at another level. This is particularly important in wide scale sire selection programs.

Repeatability

Kempthorne (1957) presented a clear description of the notion of repeatability. He derived the weight which gives the mean of the individual and the mean of the population correct emphasis in evaluating individuals with different amounts of information. He also showed how this weight could be written in terms of repeatability and the number of observations on the individual. A further discussion of this topic was given by Lush (1945).

Wadell (1959) calculated the repeatability of milk production records using all records available (13,747 records on 4,822 cows) and using only cows with the first record present (10,243 records on 4,272 cows). Requiring the first lactation to be present increased the estimate of repeatability from 0.396 to 0.427. Discussion of this increase was given.

Bereskin and Freeman (1965) used 24,830 records on 16,376 cows in 400 herds to estimate repeatability on a within-herd basis. The estimates they obtained were 0.468 for records of the cow within the herd and 0.505 for records of the cow deviated from the year-season average in which the record was made.

Butcher and Freeman (1967) estimated the correlation between 10 combination of pairs of records expressed as deviations from herdmates, that is, 1:2, 1:3, ... 4:5, for two sets of data, ABS data from California, and DHIA data from Iowa. The correlations involving first lactations tended to be lower than the correlation involving only later lactations. Also, there was a sizeable decrease in the correlation as the time separating the lactations increased. The correlations based on the Iowa data were consistently smaller than those from the ABS data. Discussion of these trends was included. Their estimates of repeatability ranged from 0.35 to 0.67.

Butcher and Freeman (1968) used several methods to estimate the relationship between different pairs of lactations of the same cow. One of the procedures used attempted to remove the effects of selection on the independent variable. A derivation of this procedure was included in the report. They concluded that all systems gave essentially the same results and that the added effort involved in the more complex procedures was difficult to justify in light of the results.

Age Distribution, Herd-Life Expectancy, and Culling Practices

Heifers

Several attempts have been made to summarize calf losses before freshening. Frick and Henry (1956) in 1956 summarized incomplete data from 13 experiment station reports throughout the United States. Based on these data they suggested that of the calves born five percent are dead at birth, an additional 10 percent die in the first six months, and another two percent die before breeding age. Of those reaching breeding age, eight percent are sterile and one percent die before freshening.

A summary of calf losses in Michigan herds on the Telfarm accounting system was presented by Meadows (1968). This summary included 281 farms and 13,954 cows. Calf losses increase from 11.9 percent to 18.4 percent as herd size increased from under 30 to over 100 cows per herd. Meadows also cited Nebraska data which indicated that 17.1 percent of the heifers born alive are lost. Death, reproductive problems, and physical injury, respectively, seem to be the most important reasons for losses. He also cited several other sources which suggest that between 30 and 32 percent of the calvings produce a heifer that entered the milking herd.

Johnson and Harpestad (1970), using Illinois DHIA herds, studied calf losses before one year of age. In their study, 13.1 percent of the

Holsteins, 4.2 percent of the Ayrshire, 18.0 percent of the Guernsey, 16.9 percent of the Jersey, and 10.5 percent of the Brown Swiss heifers born are lost before one year of age. They subdivided the results from the Holstein herds according to levels of fat production and herd size. There was a general increase in calf losses as herd size increased, but a negative trend as fat production increased. While these data indicated some general trends, the numbers present in some of the subclasses were quite low and many deviations from the general trends were present.

With calf losses as high as those found in these studies, the amount of culling that can be done on producing cows is severely limited. This is one of the major deterrants to making genetic gain in the population.

Cows

A review of the studies involving culling practices and the resulting age distributions was compiled by Andrus (1968). Thus, only some general observations about this area of investigation will be included here. In the majority of studies reviewed by Andrus, 25 to 32 percent of the herd was replaced each year and the average productive life ranged from 2.75 to 4.75 years. This corresponds roughly to 2.5 to 4.5 calvings per cow.

Robertson and Asker (1951) studied rearing proportion and average reproductive life in a breed at a stable size and during expansion. They reported that rearing proportion increased from .26 to .37 and reproductive life increased from 4 to 5.4 lactations, during expansion. They interpreted this to infer that there was a tremendous reserve for fecundity when it was needed. While this is hard to refute, the possibility that the lack of culling will increase the frequency of undesirable traits and lower the level of the quantitative traits during such periods of expansion must be acknowledged.

A review of the reasons for culling and their corresponding importance was made by Lund (1966) and by Andrus (1968). In the eight studies summarized by Lund, low production, dairy purposes, udder trouble, and sterility were the four main reasons for removal from the herd. They accounted for 29.6, 15.3, 13.8, and 13.1 percent of the culls, respectively. These four reasons of removal accounted for between 52.8 and 81.47 percent of the total culling in the eight studies.

Meadows (1968) reported the reasons for removal of cows from Michigan DHIA herds. In these data, 54.6 percent of the removals were due to low production, 17.4 percent were due to sterility, and the majority of the remaining culling was attributed to dairy purposes, physical injury, and mastitis. It is hard to believe that over 50 percent of the removals were actually due to culling for low production unless cows culled secondarily for low production were also included.

Carter (1968) reported that low production, sterility, and udder problems accounted for 27, 16, and 14 percent of the removals from New York DHIA herds.

Gurtle and Smith (1970)[1] conducted a study of culling in 16 herds in Orange and Los Angeles Counties (California) during 1968 and 1969. Their study included 16 herds and 5,644 cows of which 1,740 were removed from the herds. The herds included in the project ranged in size from 101 to 1027

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[1]Gurtle, G. G. and F. F. Smith, Farm and Home Advisors Office, County Civic Center, Visalia, California. Summary of herd culling study, Orange and Los Angeles Counties (1968-1969). Private communication. 1970.

cows and the total percent culled ranged from 16 to 50 percent with an average of 30.1 percent. Although there were vast differences from herd to herd some definite trends can be seen in the averages presented below.

Percentage of Cows Culled by Lactation Groups

1st lactation	21.7
2nd lactation	20.8
3rd lactation	18.7
4th lactation	13.8
5th lactation	8.6
6th lactation	7.1
7th lactation	4.0
8th lactation	3.1
9th and later lactations	2.06

Causes and Proportion of Culled Cows

Low production or test	40.37%
Udder problems	11.96%
Fertility problems	35.84%
Miscellaneous reasons	11.76%

The absence of cows sold for dairy purposes should be noted. Two subcategories of udder problems which contributed most to the causes for culling for udder problems were: mastitis, 6.22 percent; and broken udders, 5.10 percent. Failure to conceive was the major reason for culling for fertility problems and it was given as the reason in 24.47 percent of cows culled. Under the commercial conditions of these herds 40 percent of the cows culled were culled for low production. In examining the results from the various herds it appears that the percentage culled for production is very much affected by the percentage lost for reproductive problems, although this is not a steadfast rule.

When the figures from the California study were compared with the age distribution of Iowa cattle given by Andrus (1968), one finds some vast differences in culling procedures. The California dairymen tend to keep their cattle longer and cull less of their younger cows. This probably reflects (1) the fact that under California conditions many replacements are purchased, while in Iowa most dairymen tend to raise their own replacements, and (2) the relative cost of fresh cattle or rearing costs in the two states. Some of the remaining difference could be due to the size of the herds in the two states. Under California conditions it would appear that less emphasis is paid to the non-productive traits of each cow.

Physical Inputs and Economic Costs

This section is not intended to be a complete review of this area of the literature but rather is intended to give the reader some idea of the sources available and the problems involved in obtaining these parameters.

Heifer rearing

The problems encountered in obtaining good estimates of rearing costs can be shown in examining two articles appearing in the January and August 1970 issues of Big Farmer. In the first article, the total rearing cost, total feed costs, labor, and other costs were $245.60, $123.60, $74.00, and $48.00, respectively, while in the second article, the similar costs were $356.65, $203.63, $69.32, and $83.70, respectively. Total feed and total other costs in the second study were nearly double the equivalent costs in the first study. When the two budgets were examined more closely, it was evident that the major differences were not in the relative unit prices, but rather in the physical quantities considered necessary. It does not seem reasonable that 1789 lbs. of grain, 321 lbs. of high moisture corn, 2.8 tons of hay, 600 lbs. of grass silage, and 5.1 tons of corn silage would provide similar nutrition to 1100 lbs. of concentrate, 3617 lbs. of hay and 2.4 acres of pasture. It is differences of this nature that are evident in much of the published material, particularly in the popular press. In some of the literature on this topic, the intent of the author to make a specific point appeared to be the reason for the large discrepancies. Also, when survey data were used, the wide variability in the methods employed by specific dairymen possibly added to the variability of different estimates. The third situation that could tend to change specific estimates in a budget was the interchangeability of certain factors, for instance, the substitution of mechanization for labor. However, this is apt to be more prevalent in the cost referring to milk production than it is in calf rearing costs.

Lamb and Perkes (1969) presented a well documented evaluation of feed costs during the rearing period. This article was the result of a study conducted in Utah. In this case, the feed was measured as was the resulting growth of the heifers in the experiment. They showed a total feed consumption for the 25 months of 10,730 lbs. of hay, 1,380 lbs. of concentrate, and 380 lbs. of whole milk. While less costly rations would probably be used in the Midwest, corn silage and milk replacer substituting for at least parts of the hay and whole milk, respectively, these figures gave a rough approximation of the amounts of feed needed.

Based on survey data of New England dairymen, Frick and Henry (1956) suggested that typical feed inputs from birth to freshening would include 75 lbs. of whole milk, 50 lbs. of milk substitute, 1,200 lbs. of concentrate, 2.8 tons of hay and 2.0 tons of hay equivalent in the form of pasture.

Stone and Barker (1965) presented a budget for average rearing costs in New York state. They included \$13.26 of milk and milk substitutes, 1,279 lbs. of grain, 2.5 tons of hay, 2.5 tons of silage and \$30.05 of pasture costs.

Labor is the second major cost in heifer rearing. The majority of the labor needed is used in the first several months of the calf's life. During this period individual feeding is a normal but time consuming practice. Labor outlays of 28, 37, 30, and 34 hours were given by <u>Big Farmer</u> (August 1970), <u>Big Farmer</u> (January 1970), Iowa Extension Dairymen (1965), and Stone and Barker (1965).

Total other costs included by various authors tend to vary considerably with the completeness of the items included.

<u>Opportunity to express genetic potential</u>

Numerous examples of cows with large changes in production corresponding to changes in feeding and management levels exist (Lush and McGilliard, 1955). This should not be too surprising with heritability as low as 0.2. These ideas have been used to explain the low percent of the phenotypic difference between herds which are estimated to be genetic. Few attempts have been made, however, to quantitatively measure to what extent genetic level, level of feeding, and other factors determine the actual production level of an individual herd.

Stone et al. (1966) measured changes in milk production associated with changes in feeding and management. They used DHIA data from herds which had been on test for at least two consecutive years between 1960 and 1964. Over the five year period, there were rather consistent increases in milk production and concentrate intake; very small increases in percent-days-in-milk; and decreases in dry forage intake and pasture. The simple within-pairs-of-years correlations between change in milk production and change in concentrates fed ranged from 0.46 to 0.54. For the within-pairs-of-years regression analysis, change in concentrates fed accounted for 28 percent of the variation in change in milk production. Adding change in percent-days-in-milk increased the percent of the variation explained to 39. The simple and multiple regression coefficient within pairs of years for change in milk production per unit change of concentrates fed were 0.84 kg/kg and 0.88 kg/kg, respectively. However, the average yearly changes for New York herds were 157 kg of milk and 88 kg of grain per year. It is possible that a variable such as percent-days-in-milk may be the result of changes in many variables rather than a direct effect.

McDaniel and Corley (1967) analyzed the relationships between sire evaluations at different herdmate levels. While the specific purpose of this study was to evaluate the accuracy and repeatability of sires proven in herds of different levels of production, the study also offered an estimate of the effects of different levels of management on milk production. They used the 305-day ME first lactations of daughters of 40 AI sires, which had over a thousand daughters each, to evaluate the relationship between independent measures of the bull's breeding value at different levels of herdmate production. All daughters of these bulls with herdmate production between 4,536 and 8,164 kg (closed intervals) were divided into four groups based on the level of their herdmate's production. The daughter averages for the 40 bulls increased at a rate closely corresponding to the increase in their herdmates. The within-group estimates of predicted difference, however, decreased slowly but consistently as the herdmate level increased. The possible inappropriateness of the 0.9 regression for first-lactation cows on their herdmates of all ages was suggested as a possible reason for the decrease in predicted difference with increase in the herdmate level. They cited other authors who supported this hypothesis. Correlations and regressions of various measures of the sire's breeding value at the different herdmate levels were calculated. All of the correlations were very high, ranging from 0.86 to 0.96, indicating that the bulls ranked relatively the same at the various herdmate levels. The regression of daughter difference at the low level on the corresponding daughter difference at the high level was 0.67 and the reciprocal was 1.17. The corresponding regressions using predicted difference were 0.75 and 1.03, respectively. The standard deviations of the progeny means also indicated that differences between sires were larger at the higher herdmate levels.

Feed recommendations and economic levels of feeding

Several different approaches have been taken to provide feeding recommendations to dairy farmers. The most prevalent approach, ration balancing, has its basis in the biological needs of the animal and in the nutrient value of a feed. The second approach uses the basic information from the first approach but also includes feed intake and the relative prices of the feeds and the price of the product produced.

From the multitudes of research that have been done to establish the dietary requirements of each nutrient for growth, pregnancy, maintenance, and production, several summaries of varying completeness have been prepared. These can be characterized by publications like the _Nutrient Requirements of Dairy Cattle_ published by the National Research Council (1966) and Morrison's _Feeds and Feeding_ (1956). Some of these publications also contain average compositions of various feeds. From these publications, one can calculate the requirements of an animal at a set level of production and/or growth, and the requirements for maintenance and pregnancy, if applicable. These required amounts can then be used to formulate a ration with similar proportions and amounts of the various nutrients, hence, a balanced ration.

The second approach attempts to carry the calculations a step further, to provide the total ration which will maximize income over feed costs. Quite often this method is characterized by the use of production functions. To progress with this type of system average intakes of various feeds, the substitution rate of these feeds for one another, and the change in production with the substitution are necessary. Several examples of this approach are given by Owen and Hoglund (1970), Heady _et al_. (1956), Heady _et al_. (1964), Ronning (1961), and Dean (1961). As is pointed out by Ronning (1961), this procedure is easiest when only one nutrient needs supplementation.

Cost of milk production

Feed costs Stone and Barker (1965) presented tables which demonstrated the economics of several feeding situations. They varied the prices of milk, grain, and hay and the quality of hay in order to obtain the income over feed costs at production levels from 8,000 to 20,000 pounds. For all prices and with forage quality held constant, they showed that the additional profit for each 2,000 pound increase in production was less than for the last increase. While the general usefulness of this type of table is not questioned, the assumptions about feed intake with increasing level of production which are necessary are at best unverified. They do, however, caution the reader that the tables do not give any indication of the most profitable level of feeding dairy cattle. The feed costs per hundred weight of milk, not including the dry period, appear to range between \$1.44 and \$2.77 under the hay and grain costs considered. Since the dry period was not included, cows at the lower level of production had lower feed costs because they were able to use the lower cost hay to meet a larger proportion of their nutrient requirement. For a given hay and grain price, use of a lower quality forage increased total feed cost, both because of the lower hay intake and because of the lower value of the hay consumed.

Shultis _et al_. (1963) gave a short table of the cost per Mcal of NE. Under California conditions for that period of time, they showed natural coastal pastures to be the least expensive source of NE. Hay and grass silage were fairly competitive with irrigated pasture. Corn silage was less competitive. The low ranking of corn silage appeared to be due to the relatively high price and the low NE content hypothesized by the authors.

Specific estimates of feed cost per hundred weight of milk will be given in the section on total cost of milk production.

Labor needs The variability in labor needs for the dairy operation are subject to the same type of variation as are the other physical and cost parameters. In addition, they are extremely dependent upon the physical facilities used. The labor requirement for a large mechanized dairy operation with loose housing and on a ration high in corn silage is hardly comparable to that for a small herd housed in a stanchion barn with hay as the major source of roughage. Thus, the definition of labor requirements for different types of operations will not be specifically given here. Only general reference to several sources of information will be provided.

Fuller and Jensen (1962b) presented graphically the amounts of labor necessary for the different tasks involved in the dairy operation and demonstrated the effect of herd size, season, and other variables on these labor requirements. In an earlier bulletin (Fuller and Jensen, 1962a), they also examined the labor requirements for alternative dairy chore systems in loose housing.

James (1968) provided a table of the requirements for chore labor for different types of dairy housing, milking, and feeding systems for different herd sizes. These ranged from 112 hours per cow for 15 cows in an unmechanized stanchion barn to 48 hours per cow for a 60-cow herd in loose housing with a double-five herringbone. An evaluation of seasonal labor requirements and a breakdown for other classifications was also given.

Smith (1970) presented summarized data from 568 New York dairy farms. The number of cows per man increased from 24 cows per man in herds of less than 40 cows to 34 cows per man in herds larger than 100 cows.

Saupe (1971) gave labor costs for three different herd sizes. Each herd size was divided into a low, average, and high group. Labor cost decreased within each group and as herd size increased. The labor cost per hundred weight of milk was $1.51 for the low third of the small herd size and $0.44 for the high third of the large herd size.

Kimball (1966) provided figures from 24 large dairy operations which were below or above average in production per cow. When the cost of labor per hundred weight of milk was calculated, including labor at $250 per month, the below average farms required $1.10 per hundred weight of milk for labor, while the above average herds required $0.91 of labor. Both groups had an average herd size of 62 cows.

Total investment The total amount of capitalization on a dairy farm is very closely related to relative land values, degree of mechanization, proportion of the needed feed that is raised on the farm, and the number of young stock raised. In most cases, total investment will refer to the investment for all three phases of the dairy operation: heifer rearing, crop production, and milk production.

Smith (1970) showed that from 1956 to 1968 the total capital investment on New York dairy farms had risen from $1,180 to $1,930 per cow. In several breakdowns of the 1968 investment, he showed that machinery and equipment, and livestock each accounted for slightly over 22 percent of the total investment, land and buildings accounted for just over 45 percent, and investment in feed and supplies on hand accounted for seven percent of the total. He also showed that the total investment per cow increased irregularly, while the total investment per man increased substantially as herd size increased. This was explained as resulting from the increase in mechanization with the increased herd size. Similar investments per cow were given for several midwestern states. Each state except Wisconsin had substantially higher investments per cow than New York. In most cases, this probably represented the higher involvement in other enterprises, thus yielding a high cost per cow when total investment was considered. This does not seem to be a relevant comparison when it is expressed on a per cow basis.

Buxton and Jensen (1968) gave average investment in dairy facilities per cow for different herd sizes. These figures ranged from $1,066 per cow for a herd of 13 cows housed in a stanchion barn to $472 per cow for a herd of 148 cows housed in a loose housing loafing barn. The fastest decrease in the per cow cost came with the increase in herd size from 13 to 30 cows ($1,066 to $704).

Kimball (1966) showed that for large dairy operations in Wisconsin, total farm investment per cow decreased as herd size increased from 45 to 110 cows. However, herds producing at the higher levels of production had higher investment costs particularly at the smaller herd size.

Saunders _et al_. (1970) gave the total investment for a 100-cow dairy enterprise with dry-lot feeding at $1,175 when all feed was purchased and approximately $1,900 when the silage was raised. Cattle accounted for $460 of the investment; building, milking, and feeding facilities accounted for an additional $600 of the total investment.

Shultis _et al_. (1963) presented investment figures for a 150-cow herd producing market milk and a 50-cow herd producing manufacturing milk. For the 50-cow herd, investments of $348.70, $64.80, and $821.10 per cow were reported for the milking herd, heifer enterprise, and the forage enterprise, respectively. The similar figures for the 150-cow herd producing market milk were $479.34, $79.16, and $915.74, respectively. The extremely low investment in the dairy herd resulted from low cow prices and very little need for shelter under California conditions.

As can be seen from the reports cited above, capital investment in the dairy herd per cow has been constantly increasing over time. Wide variation has also been noted for different areas of the country. Part of this variation is caused by the difference in the amount of the feed produced and in the percent of the replacements raised. Other factors causing variation are: land cost per unit of productivity, need for cattle housing, and amount of mechanization.

Total cost of milk production Several factors exert primary influence on the cost of milk production. Both the estimate of the total costs of production and the total costs of production per cow are markedly influenced by the level of production and the herd size. As the level of production increases the total costs increase, but the total cost per cow tends to decrease. This relationship holds because for each additional increase in production the total cost is increased only with respect to the variable costs. With an increase in herd size, the total costs increase but the total costs per cow may decrease through fuller use of the fixed facilities. Thus, to learn about the efficiency of the fixed and random costs free of herd size and production level would be helpful but is often not possible. Also, the problem of including all of the costs of milk production is continually faced when evaluating the costs of production.

Saupe (1971) presented summary figures from the Wisconsin Farm Records Program. Total costs per hundred weight of milk ranged from $6.17 for the low third of the small herd size (average of 26 cows) to $3.95 for the high third of the large herd size (average of 76 cows). Operating cost accounted for slightly less than 50 percent of the total costs per hundred weight in the small herds and over 60 percent in the large herds. Depreciation and the charge for capital accounted for 25 to 29 percent of the total costs for all herd sizes. Charge for operator and family labor accounted for 25 percent of total cost per cow in the small herd size but only about 12.5 percent in the large herd size. Total investment ranged from approximately $1,650 to $2,000 per cow.

Kimball (1966) used data from 18 large dairy farms to prepare graphs of the average cost of producing milk at three levels of production. The average cost per hundred weight ranged from $3.85 for 45-cow herds with 10,000 lb. production per cow to $2.75 for 110-cow herd producing at the 14,000 lb. level. He showed that the decrease in cost with additional cows was faster for the low level of production than for the higher levels of production. However, a fairly large difference in favor of higher production level existed for all herd sizes studied.

Shultis _et al_. (1963) showed total cost per hundred weight of milk for a herd of 150 cows producing 12,500 pounds per cow to be $3.75 per cwt. Of this cost, $1.85 was feed cost, $0.72 was labor cost, and $0.34 was cow depreciation cost. The similar costs for a 50-cow herd producing 10,000 pounds of manufacturing milk were: $3.38, $1.74, $0.79, and $0.36.

Saunders _et al_. (1970) presented budgets for 100-cow herds on four experimental rations. Total production costs _excluding_ operators labor and management were $5.73, $6.54, $6.47, and $5.24 for herds on the four rations. Total feed costs for the four systems were $3.30, $4.14, $4.05, and $2.82, respectively. Fixed costs accounted for $0.75 per hundred weight of milk. Part of the reason for the unusually high feed costs was the high rate of grain feeding in systems one and four and the high cost of the complete feed used in systems two and three.

Wisconsin farm enterprise budgets (1968) contained cost comparisons for the total dairy operation at 10,000, 12,000, 14,000, and 16,000 pound levels of milk production. The total cost of production per hundred weight of milk was: $4.64, $4.05, $3.66, and $3.45 for each of the production levels, respectively. Feed cost for the cows accounted for $2.21, $2.02, $1.90, and $1.88 of the total per hundred weight costs. The corresponding ownership costs were: $1.06, $0.88, $0.79, and $0.71 per hundred weight of milk. As can be seen in the comparison with previous studies, extreme differences exit in the estimates of the various costs of production, even during the same time period. While part of these differences can be explained by geographic differences, some of the differences appear to be based on a poor source of data or on unrealistic assumptions.

Present value of profit

Dernburg and McDougall (1968) discussed discounting and the present value of an asset for several different situations. They showed that the present value of an asset $(P_O) = \frac{P_t}{(1+i)^t}$, where P_t = the value received in year t; and i = the interest rate. When the asset yields a return each year, the present value $(P_O) = \sum_{j=1}^{t} \frac{R_j}{(1+i)^j}$, where R_j is the return in year j; and i is the constant interest rate.

Lindhé (1968) used a discounting procedure similar to the one just mentioned in evaluating the total economy in an AI-breeding scheme with different levels of six factors: (a) the proportion of the population which is inseminated by young bulls; (b) the size of the progeny groups;

(c) the number of ampules from each bull; (d) the selection for growth rate after performance testing; and (e) the heritability for milk yield. In making the evaluation (genetic and economic) two traits, milk production and growth rate, were considered. Lindhé demonstrated that under the assumptions that he set forth the optimum level of investment (criterion - marginal rate of interest should not be less than 10 percent) would yield 94 percent of the maximum genetic gain. Lindhé concluded that increasing the number of services per bull appeared to be a more economical method of attaining a more effective breeding program than increasing the number of bulls with same number of doses.

Hill (1971) evaluated the cost-effectiveness of several breeding schemes. He stated that the cost of each program and the potential economic returns to the national industry must be considered and that it is no longer sufficient merely to compare rates of genetic improvement. The method of discounted cash flow was used to accomplish this end. He suggested the use of the current interest rate as the discount rate, while Lindhé suggested the use of a higher interest rate. Lindhé's suggestion was based on the possibility of genetic slippage and could be considered as including a safety or risk factor.

METHOD OF PROCEDURE

The purpose of this study was to evaluate the profitability of dairy herds under diverse systems of female selection. Evaluation of each selection system under different levels of genetic gain in the sires, different herd sizes and production levels, and different levels of several economic factors should make the results and the conclusions drawn from this study applicable to the majority of the dairymen in this area of the country. The levels of each factor are given in Figure 1. The parameters used in the study were intended to be relative to the population of commercial Holstein cattle in the Northern Midwest. With the exception of several parameters associated with cattle valuation and sale practices, most of the remaining parameters would also fit purebred breeder herds in this area.

During this study, the lack of estimates of certain parameters became evident. For example, little is known about the quantitative change in veterinary costs with increasing age, or with increasing level of production. While this type of parameter would affect each of the culling systems differently, it was hoped that its effect would not be large enough to materially change the results of this study.

Several abbreviations and definitions that are used throughout the manuscript are included here.

ME production = production adjusted to mature-equivalent basis.

HE production = production expressed on heifer-equivalent basis (two years and four months). All genetic parameters will be expressed on an HE basis unless specified differently.

I. Cow Selection Systems

1. All selection on calves -- raise only enough females to replace involuntary culls
2. Select milking cows on highest breeding value -- freshen all females
3. Select youngest cows possible -- freshen all females
4. Make all voluntary culling during the two-year-old lactation -- freshen all females

II. Sire Selection

1. Best sires from a stud similar to those now available
2. Breed-average sires from a stud similar to those now available
3. Fastest genetic gain possible

III. Herd Size and Production Level

1. 40 milking cows -- 11,500 ME milk production
2. 40 milking cows -- 14,000 ME milk production
3. 40 milking cows -- 16,500 ME milk production
4. 120 milking cows -- 11,500 ME milk production
5. 120 milking cows -- 14,000 ME milk production
6. 120 milking cows -- 16,500 ME milk production

IV. Rearing Cost

1. $250.00
2. $325.00
3. $400.00

V. Feed Cost per Mcal of Net Energy for Lactating Cows (NE_L)

1. $0.024/Mcal NE_L
2. $0.033/Mcal NE_L
3. $0.045/Mcal NE_L

VI. Net Price of Milk per One-hundred Pounds (cwt)

1. $5.00/cwt
2. $5.50/cwt
3. $6.50/cwt

Figure 1. Outline of the factors considered

Cow Periods (CP) = the sum of the number of days that each cow is in the herd (milking and dry) divided by the number of days in the period (396).

Calculation of Genetic and Phenotypic Levels of Each Herd

A herd was simulated for 20, 13-month periods for each of the 72 factorial combinations of the levels of factors I, II, and III in the outline in Figure 1. The resulting production information was combined with the other physical data for the herd and then each herd period was evaluated at all factorial combinations of economic factors (the last three factors in Figure 1) to obtain income, expense, and profit for the herd period.

Three measures of milk production were calculated for each herd period. They were (1) the genetic level (HE) of the females which produced a calf in period I, (2) the total actual pounds of milk produced by the herd in the I^{th} period, and (3) the ME extended 305-day lactation average of all cows freshening in the herd in the I^{th} period. Each herd was carried through 20, 13-month periods of the particular selection scheme involved. (Under measure (2), the total pounds of milk divided by 13/12 and herd size is equivalent to the rolling herd average used in DHI.)

The algorithm used to obtain the genetic level of the herd included the average genetic level (at birth) of all cows in lactation J and the cumulative genetic gain made from selection previous to lactation J. The weighted average of the genetic levels of the parents from two periods was used to account for heifers freshening with their first calf at 28 months (2 periods + 2 months). The genetic level for the cows in each lactation was weighted by PNC_J, the ratio of the number of cows calving in the J^{th}

lactation to the total number of cows calving in the herd period. The resulting mean was the average genetic level for all cows producing calves in year I. The average genetic level of the cows that calved in a herd (genetic level of the herd) of a particular size, production level, cow selection scheme, and sire selection system during period I were calculated from the algorithm that follows:

$$GC_I = \sum_{J=1}^{10} PNC_J \left[(11/26)\ (GC_{I-J-1} + GB_{I-J-2}) + (2/26)\ (GC_{I-J-2} + GB_{I-J-3}) + CDG_J\right]$$

where,

GC_I = the genetic average of all cows in the herd that produced a calf in period I,

GB_I = the genetic value in period I of the bulls in the sire selection scheme used,

PNC_J = the proportion of the total number of different cows in the herd that produce a calf at lactation J,

CDG_J = the genotypic gain resulting from selection made through lactation J-1,

11/26 = 1/2, the weight for each parent's genetic level, times 11/13, the weight to account for the average birth date of the heifers.

In this algorithm, genetic trend was accounted for by building the genetic value of the calf from the average of the parent levels at the time of the calf's birth. Thus, the parent levels reflected any selection that had been practiced. The selection parameters, DP_J, $CDP1_J$, CDP_J, CDG_J were constant for all periods.

The total actual production of each herd was calculated by a similar algorithm. The genetic base (at birth) for the cows in each lactation was calculated as above except that a further lag was needed in the weights to account for the average freshening date of cows producing milk in the J^{th} lactation during period I.

The algorithm was divided into two parts: those cows which left the herd after five months of production, and those cows which completed the whole lactation. The production of each group was adjusted for the selection that had taken place and for the opportunity that the herd had to express its genetic ability (β_L). The final two adjustments were for age and for length of lactation.

The actual production of the herd in period I equaled:

$$PL_I = \sum_{J=1}^{10} D_J[(GBASE1_{I,J} + CDP_J - (\frac{D_J - NC_J\ PLI_J}{D_J})\ DP_J)\beta_L + CONST_L]$$

$$(FME_1/FME_J)\ (1/FE152_J) + NC_{J+1}\ [(GBASE2_{I,J} + CDP1_J)\beta_L + CONST_L]$$

$$(FME_1/FME_J)\ (1/FE323),$$

$GBASE1_{I,J} = (9/26)\ (GC_{I-J-1} + GB_{I-J-2}) + (4/26)\ (GC_{I-J-2} + GB_{I-J-3}),$

= the genetic base at birth of the cows producing in the J^{th} lactation in time period I, that leave the herd at five months,

$GBASE2_{I,J} = (7/26)\ (GC_{I-J-1} + GB_{I-J-2}) + (6/26)\ (GC_{I-J-2} + GB_{I-J-3}),$

= the genetic base at birth of the cows producing in the J^{th} lactation in time period I, that remain in the herd,

where,

PL_I = the actual pounds of milk produced in period I by the herd,

GC_I = the genetic average of all cows in the herd that produced a calf in period I,

GB_I = the genetic value in period I of the bulls in the sire selection scheme used,

NC_J = the number of cows that start lactation J (Tables 15-20),

$D_J = NC_J - NC_{J+1}$ = the number of cows that leave the herd during their J^{th} lactation,

PLI_J = the percent of the cows that are involuntarily lost during the J^{th} lactation,

DP_J = the phenotypic result in lactation J of selection made in lactation J (the selection differential in terms of lactation J for selection made in lactation J),

$CDP1_J$ = the phenotypic result in lactation J of all selection made through lactation J,

CDP_J = the phenotypic result in lactation J of all selection made through lactation J-1,

CDG_J = the genotypic result of selection made through lactation J-1 (These four selection parameters are constant for all periods.),

β_L = the regression of the daughter difference from herdmates in the L^{th} level of production on the daughter difference from herdmates in the medium level of production (modification of the estimates calculated by McDaniel and Corley (1967); 0.90, 1.00, 1.10 for the low, medium, and high production levels, respectively,

$CONST_L$ = the adjustment necessary to make the initial production level of the herd equal to β_L times the genetic level of the herd;

-649, 0, and 601 for the low, medium, and high production levels, respectively,

FME_1 = the Mature Equivalent factor for cows in lactation 1,

FME_J = the Mature Equivalent factor for the cows in lactation J (Table 1),

FE323 = the extension factor for lactations of length 323 days (0.95),

FE152 = the extension factor for lactations of length 152 days for cows in lactation J (Table 1),

and the constants (7/26, 5/26, etc.) were adjustments for the 28-month age at calving and for the average calving date of cows producing in the J^{th} lactation in the I^{th} period.

The extended mature equivalent 305-day lactation production of the herd in period I was equivalent to PL_I, except that FME_1/FME_J was replaced by FME_1, and the correction for length of lactation was omitted. The total ME production of the herd was divided by the total number of different cows in the herd period to obtain the average ME production per cow, while the total actual production of the herd was divided by the number of cow periods (herd size) to obtain the DHI rolling average.

Calculation of Income, Expense and Profit

Income, expense, and profit were calculated for each herd period at each level of the economic factors. Income was calculated by multiplying the unit price times the total units of each commodity produced in the herd. The commodities considered and units of each commodity were:

1. Milk--actual pounds of milk sold,
2. Cull heifer calves--number of heifer calves sold (Five percent

Table 1. Genetic and phenotypic parameters on a mature-equivalent and two-year-old basis

Mature equivalent variances:	$\sigma_P = 2500$	$\sigma_G = 1118$	$\sigma_{E_P} = 968$	$\sigma_{E_T} = 2015$
Two-year-old variances:	$\sigma_P = 1953$	$\sigma_G = 873$	$\sigma_{E_P} = 756$	$\sigma_{E_T} = 1574$

Heritability: $h^2 = .20$ constant for all lactations; genetic correlations among lactations = 1

Repeatability:

	Lactation								
Lactation	1	2	3	4	5	6	7	8	9
2	.45								
3	.40	.50							
4	.35	.45	.55						
5	.35	.40	.50	.55					
6	.35	.40	.50	.50	.55				
7	.35	.40	.45	.50	.50	.55			
8	.35	.40	.45	.50	.50	.50	.55		
9	.35	.40	.45	.45	.50	.50	.50	.55	
10	.35	.40	.45	.45	.45	.45	.50	.50	.55

Mature equivalent and extension factors:

Average age	2-4	3-5	4-6	5-7	6-8	7-9	8-10	9-11	11-0	12-1
ME factor[a]	1.28	1.15	1.06	1.02	1.00	1.00	1.01	1.02	1.04	1.06
Ext. factor 152 days	1.75	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
"Ext. factor" 323 days	.9524	.9524	.9524	.9524	.9524	.9524	.9524	.9524	.9524	.9524

[a]Average of the regional factors calculated by USDA (McDaniel et al., 1967).

death losses were subtracted from the figures in Table 2 before evaluating each of these.),

3. Cull bull calves--number of bull calves sold (Five percent death losses were subtracted from the figures in Table 2 before evaluating each of these.),
4. Cull cows--pounds of cull cows sold (Three percent death losses were subtracted from the figures in Table 2 before evaluating each of these.), calculated as the number of cows of each age sold times the weight at that age,
5. Cows sold for dairy purposes--number of cows sold for dairy (Three percent death losses were subtracted from the figures in Table 2 before evaluating each of these.).

The different levels of the unit prices for the five income commodities are found in Table 3. The expenses for the herd were calculated in a similar manner. The expenses considered were:

1. Non-variable cost dependent on herd size - * items in the budget, Tables 23 and 24 (This total was multiplied times 13/12 to put it on a period basis.),
2. Interest on cows - variable valuation of cows dependent upon production levels and rearing cost, Table 3. (This was also multiplied times 13/12 to put it on a period basis.),
3. Cost of artificial breeding - number of first services in the herd (calculated as 110 percent of the number of calves born in the herd, Table 2),

4a. Feed costs for maintenance, growth, and pregnancy - requirements of Net Energy for lactating cows (NE_L) were calculated from the ten-

Table 2. Numbers of animals of different classes for each of the selection systems, herd sizes, and production levels

	40-cow herd			120-cow herd		
Production level:	Low	Medium	High	Low	Medium	High
		Cow selection scheme 1				
Calves born	45.94	45.94	45.94	137.80	137.80	137.80
Heifer calves sold	9.88	10.33	10.57	28.25	28.94	30.32
Bull calves born	22.97	22.97	22.97	68.90	68.90	68.90
Cull cows	9.64	9.64	9.64	28.92	28.92	28.92
Cows sold dairy	0.00	0.00	0.00	0.00	0.00	0.00
Cow periods	40.00	40.00	40.00	120.00	120.00	120.00
		Cow selection scheme 2				
Calves born	51.74	52.18	52.54	153.36	154.46	156.00
Heifer calves sold	0.00	0.00	0.00	0.00	0.00	0.00
Bull calves born	25.87	26.09	26.27	76.68	77.23	78.00
Cull cows	19.14	19.83	20.49	54.44	56.38	58.39
Cows sold dairy	0.00	0.00	0.00	0.00	0.00	0.00
Cow periods	40.00	40.00	40.00	120.00	120.00	120.00
		Cow selection scheme 3				
Calves born	51.78	52.21	52.64	153.54	154.76	156.00
Heifer calves sold	0.00	0.00	0.00	0.00	0.00	0.00
Bull calves born	25.89	26.10	26.32	76.77	77.38	78.00
Cull cows	6.77	6.77	6.78	20.55	20.42	20.32
Cows sold dairy	12.38	13.07	13.75	33.96	36.07	38.18
Cow periods	40.00	40.00	40.00	120.00	120.00	120.00
		Cow selection scheme 4				
Calves born	51.80	52.20	52.64	153.54	154.76	156.00
Heifer calves sold	0.00	0.00	0.00	0.00	0.00	0.00
Bull calves born	25.90	26.10	26.32	76.77	77.38	78.00
Cull cows	19.16	19.84	20.53	54.51	56.49	58.50
Cows sold dairy	0.00	0.00	0.00	0.00	0.00	0.00
Cow periods	40.00	40.00	40.00	120.00	120.00	120.00

Table 3. Unit prices of income and expense items

	Income items
1. Milk (net price received)	\$5.00 / cwt (low price)
	\$5.50 / cwt (medium price)
	\$6.50 / cwt (high price)
2. Cull heifer calves	\$50.00 / head
3. Bull calves	\$40.00 / cwt
4. Cull dairy cows	\$0.19 / pound
5. Cows sold dairy purposes	\$300.00 / head (low production level)
	\$325.00 / head (medium production level)
	\$375.00 / head (high production level)
	Expense items
1. Non-variable costs	\$12,655.00 / herd (40 cow herds) / year
	\$27,232.00 / herd (120 cow herds) / year
2. Interest rate on cows	\$0.07 / \$1.00 of valuation / year
Valuation	\$325.00, \$375.00, \$425.00 / cow (low production level and low, medium and high rearing cost, respectively)
	\$350.00, \$400.00, \$450.00 / cow (medium production level and low, medium and high rearing cost, respectively)
	\$375.00, \$425.00, \$475.00 / cow (high production level and low, medium and high rearing cost, respectively)
3. Cost of artificial insemination	\$7.50 / first insemination (breed-average bulls)
	\$10.00 / first insemination (high bulls)
	\$15.00 / first insemination (fastest genetic gain bulls)
4. Cost of feed	\$0.024 / Mcal Net $Energy_L$ (low cost)
	\$0.033 / Mcal Net $Energy_L$ (medium cost)
	\$0.042 / Mcal Net $Energy_L$ (high cost)

Table 3 (Continued)

5. Rearing cost of heifers	\$250.00 / head (low cost)
	\$325.00 / head (medium cost)
	\$400.00 / head (high cost)
6. Additional cost of milk for higher levels of milk production (based on rolling herd average)	\$0.05 / cwt of milk (13,000-15,000)
	\$0.10 / cwt of milk (15,000-17,000)
	\$0.15 / cwt of milk (17,000-19,000)
	\$0.20 / cwt of milk (above 19,000)

tative revision of the National Research Council (NRC)[1] recommendations. The appropriate daily maintenance and growth requirement was multiplied by 335 days and the appropriate daily requirement for maintenance, growth and pregnancy was multiplied times 61 days to give the total requirement for the 13 months. For cows leaving the herd, the maintenance and growth requirement was multiplied times 152 days. Each requirement was multiplied times the number in the lactation group and the product was summed over all lactations and groups. A three percent wastage allowance was added to all feed needs,

4b. Feed costs for milk production - the unpublished NRC requirement[1] for 3.5 percent milk was used as the basis of the feed needed to sustain milk production. The authors of the NRC requirements recommend that a three percent increase be added to the basic re-

[1]Jacobson, N. L., Department of Animal Science, Iowa State University, Ames, Iowa. Tentative revisions of the nutrient requirements of dairy cattle. Private communication. 1971.

quirement for each 10 kg of milk produced over 20 kg. This additional requirement was determined by calculating the production level for three segments of the lactation, determining the additional Mcal needed, averaging the three, and adding this to the basic requirement. This adjusted requirement was multiplied times the total pounds of milk produced by the herd,

5. Rearing cost of heifers entering the milking herd - number of first calf heifers entering the herd (Table 2),
6. Additional cost of milk production above 13,000 pounds - based on the DHI rolling average. This additional cost was included to account for the added veterinary and labor costs at the higher levels of production. There is also some evidence that the cost of feed for cows producing at a high level relative to their genetic ability would tend to be higher than for cows producing at low and medium levels.

The unit price of each of these items is found in Table 3. Profit was defined as income minus expense.

Description of the Factors Being Simulated

Each of the factors given in the previous outline, Figure 1, are defined in this section. Use of the Table of Contents will be helpful in finding specific items.

Cow selection systems

Four culling schemes were chosen for evaluation. Each of these four was chosen to maximize one or more of the following objectives: (a) added milk production due to increasing age (approaching maturity); (b) added milk production due to increasing the speed in which the genetic gain in the males is incorporated; (c) added milk production in this generation (phenotypic) and the next generation (genetic) due to selection within the females in the herd; and (d) decreased cost due to rearing fewer heifers.

Selection system one   All voluntary selection was practiced on the estimated breeding value of the baby calves born and only enough heifers were raised to replace the involuntary culls and maintain herd size. The index used to estimate the breeding values on these calves included the calf's dam, paternal half-sibs, and maternal half-sibs. The average R_{IG} for all calves born was taken to be equal to 0.5. CDG_J was equal to $\bar{i}R_{IG}\sigma_G$. The phenotypic parameters $CDP1_J$ and CDP_J were equal to CDG_J. All selection was made on relative information. The selection intensities possible with each herd size and production level are given later.

This selection system tends to minimize replacement cost. The intensity of the selection on these calves is high, but the genetic improvement is relatively small because of the low accuracy of selection. Since the selection is made early, however, all lactations and calves born to these cows benefit from the selection.

Selection system two   Selection was practiced at all lactations. The cows with the highest breeding value based on their own records were kept and all heifers were raised. A complete description of the method used to obtain the phenotypic and genotypic parameters needed for this system is given in the section entitled Selection parameters for selection system two.

This selection system tends to combine objectives (a), (b), and (c). The main reason for each additional selection is to account for the genetic trend in the cows entering the herd each year. The secondary reason is to make use of the additional amount of information on the cow with each succeeding lactation. The number of cows that are producing at mature ages should be decreased with an increase in the genetic trend of the two-year-old cows.

Selection system three The oldest cows in the herd were culled and all heifer calves were raised. This selection system was aimed at maximizing objective (b) at the expense of the other objectives. When the number of cows of the same age was greater than the number to be culled, the cows that were culled were chosen at random from those available. Thus, the phenotypic and genotypic selection differentials for this system were all zero. The results of this selection system should vary with the amount of genetic gain that is being accomplished through sire selection. The genetic level of this system will only increase through gain made in sires selected and the phenotypic level of this system will probably be low, because of the lack of cows in mature-age groups.

Selection system four All voluntary selection was practiced on the estimated breeding values of the two-year-old cows and all heifer calves were raised and freshened. The index used to estimate the breeding value of these heifers included the cow's own record, her dam's records, and the records of her maternal and paternal half-sibs. The average index for first calf heifers was 0.1654 (cow's own record) + 0.5110 (records of her paternal half-sibs) + 0.0816 (records of her dam) + 0.0184 (records of her maternal half-sibs). The regressions are average values for the number of records in each relative group. This would yield an average R_{IG} of 0.5818. The estimate of the genetic gain made through this one selection (CDG_J) was calculated as $\bar{i}R_{IG}\sigma_G$. With no further voluntary culling, this was the total genetic gain for all succeeding lactations. CDP_J and CDG_J were equal to zero for the first lactation since no culling had been practiced previous to the first lactation. $CDP1_1$, $CDP1_J$ and CDP_J for lactations two through 10 were calculated as the $\beta_{X_i I} CDG_1$.

This selection system tends to maximize objectives (a) and (c). As in selection system one, the selection is practiced early in life and all but the first calf of these cows benefit from this selection. With no voluntary selection being practiced after the first lactation, a number of the cows remain in the herd to a mature age.

The estimates of CDP_J, $CDP1_J$, DP_J, CDG_J used for each culling system are presented in Tables 4-9. All of the difference between the different herd sizes and production levels within culling system are due to difference in rearing success (Table 14). These differences are quite small, especially in the early lactations where the larger number of lactations are involved. In selection system one, calf selection, the cumulative phenotypic measures are all equal to the genetic differential because all selection was based on relative information. The corresponding phenotypic selection differentials were all zero because no selection was practiced on the producing cows. The method of obtaining the parameters given for system two is explained in detail in the next section. The difference between $CDP1_J$ and CDP_{J+1} can be explained as the change in temporary environmental effects from one lactation to the next. In selection system four, selection on EBV of two-year-old heifers, the continuing reduction of the cumulative phenotypic differential is due to reduction in the correlation between first lactation and succeeding lactations, Table 1.

Table 4. Phenotypic and genotypic selection parameters[a]: 40-cow herd, low-production level

Lactation (J)	Selection scheme															
	1				2				3				4			
	DP_J[b]	$CDP1_J$[c]	CDP_J[d]	CDG_J[e]	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J
0 (calf)	-	-	-	385	0	0	0	0	0	0	0	0	0	0	0	0
1	0	385	385	385	900	900	0	0	0	0	0	0	1687	1687	0	0
2	0	385	385	385	900	1350	400	195	0	0	0	0	0	921	921	572
3	0	385	385	385	950	1750	800	400	0	0	0	0	0	851	851	572
4	0	385	385	385	900	2275	1300	605	0	0	0	0	0	781	781	572
5	0	385	385	385	800	2650	1800	800	0	0	0	0	0	781	781	572
6	0	385	385	385	625	2775	2150	960	0	0	0	0	0	781	781	572
7	0	385	385	385	470	2875	2400	1070	0	0	0	0	0	781	781	572
8	0	385	385	385	370	2950	2600	1145	0	0	0	0	0	781	781	572
9	0	385	385	385	320	3000	2750	1195	0	0	0	0	0	781	781	572
10	0	385	385	385	220	3050	2850	1245	0	0	0	0	0	781	781	572

[a]All parameters are expressed on a ME basis. These four selection parameters are constant for all periods.

[b]DP_J = the phenotypic result in lactation J of selection made in lactation J (the selection differential in terms of lactation J for selection made in lactation J).

[c]$CDP1_J$ = the phenotypic result in lactation J of all selection made through lactation J.

[d]CDP_J = the phenotypic result in lactation J of all selection made through lactation J-1.

[e]CDG_J = the genotypic result of selection made through lactation J-1.

Table 5. Phenotypic and genotypic selection parameters[a]: 40-cow herd, medium-production level

Lactation (J)	Selection scheme 1				2				3				4			
	DP_J[b]	$CDP1_J$[c]	CDP_J[d]	CDG_J[e]	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J
0 (calf)	-	-	-	402	0	0	0	0	0	0	0	0	0	0	0	0
1	0	402	402	402	925	0	0	0	0	0	0	0	1755	1755	0	0
2	0	402	402	402	950	1400	420	205	0	0	0	0	0	957	957	594
3	0	402	402	402	975	1800	840	415	0	0	0	0	0	884	884	594
4	0	402	402	402	925	2350	1350	625	0	0	0	0	0	812	812	594
5	0	402	402	402	850	2750	1850	820	0	0	0	0	0	812	812	594
6	0	402	402	402	625	2900	2200	980	0	0	0	0	0	812	812	594
7	0	402	402	402	490	3000	2450	1090	0	0	0	0	0	812	812	594
8	0	402	402	402	390	3100	2650	1165	0	0	0	0	0	812	812	594
9	0	402	402	402	340	3150	2800	1215	0	0	0	0	0	812	812	594
10	0	402	402	402	240	3200	2900	1265	0	0	0	0	0	812	812	594

[a]All parameters are expressed on a ME basis. These four selection parameters are constant for all periods.

[b]DP_J = the phenotypic result in lactation J of selection made in lactation J (the selection differential in terms of lactation J for selection made in lactation J).

[c]$CDP1_J$ = the phenotypic result in lactation J of all selection made through lactation J.

[d]CDP_J = the phenotypic result in lactation J of all selection made through lactation J-1.

[e]CDG_J = the genotypic result of selection made through lactation J-1.

Table 6. Phenotypic and genotypic selection parameters[a]: 40-cow herd, high-production level

Lactation (J)	Selection scheme 1				2				3				4			
	DP_J[b]	$CDP1_J$[c]	CDP_J[d]	CDG_J[e]	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J
0 (calf)	-	-	-	410	0	0	0	0	0	0	0	0	0	0	0	0
1	0	410	410	410	950	950	0	0	0	0	0	0	1787	1787	0	0
2	0	410	410	410	1000	1500	450	215	0	0	0	0	0	974	974	605
3	0	410	410	410	1000	1900	900	425	0	0	0	0	0	900	900	605
4	0	410	410	410	950	2375	1400	640	0	0	0	0	0	827	827	605
5	0	410	410	410	900	2850	1900	840	0	0	0	0	0	827	827	605
6	0	410	410	410	650	3000	2250	1000	0	0	0	0	0	827	827	605
7	0	410	410	410	500	3100	2500	1110	0	0	0	0	0	827	827	605
8	0	410	410	410	400	3200	2700	1185	0	0	0	0	0	827	827	605
9	0	410	410	410	350	3250	2850	1235	0	0	0	0	0	827	827	605
10	0	410	410	410	250	3300	2950	1285	0	0	0	0	0	827	827	605

[a]All parameters are expressed on a ME basis. These four selection parameters are constant for all periods.

[b]DP_J = the phenotypic result in lactation J of selection made in lactation J (the selection differential in terms of lactation J for selection made in lactation J).

[c]$CDP1_J$ = the phenotypic result in lactation J of all selection made through lactation J.

[d]CDP_J = the phenotypic result in lactation J of all selection made through lactation J-1.

[e]CDG_J = the genotypic result of selection made through lactation J-1.

Table 7. Phenotypic and genotypic selection parameters[a]: 120-cow herd, low-production level

Lactation (J)	Selection scheme 1				2				3				4			
	DP_J[b]	$CDP1_J$[c]	CDP_J[d]	CDG_J[e]	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J
0 (calf)	-	-	-	368	0	0	0	0	0	0	0	0	0	0	0	0
1	0	368	368	368	800	800	0	0	0	0	0	0	1595	1595	0	0
2	0	368	368	368	850	1250	385	185	0	0	0	0	0	869	869	540
3	0	368	368	368	900	1650	770	385	0	0	0	0	0	804	804	540
4	0	368	368	368	850	2100	1240	580	0	0	0	0	0	738	738	540
5	0	368	368	368	700	2450	1700	760	0	0	0	0	0	738	738	540
6	0	368	368	368	600	2575	2050	915	0	0	0	0	0	738	738	540
7	0	368	368	368	450	2675	2300	1025	0	0	0	0	0	738	738	540
8	0	368	368	368	350	2750	2500	1100	0	0	0	0	0	738	738	540
9	0	368	368	368	300	2800	2650	1150	0	0	0	0	0	738	738	540
10	0	368	368	368	200	2850	2750	1200	0	0	0	0	0	738	738	540

[a]All parameters are expressed on a ME basis. These four selection parameters are constant for all periods.

[b]DP_J = the phenotypic result in lactation J of selection made in lactation J (the selection differential in terms of lactation J for selection made in lactation J).

[c]$CDP1_J$ = the phenotypic result in lactation J of all selection made through lactation J.

[d]CDP_J = the phenotypic result in lactation J of all selection made through lactation J-1.

[e]CDG_J = the genotypic result of selection made through lactation J-1.

Table 8. Phenotypic and genotypic selection parameters[a]: 120-cow herd, medium-production level

Lactation (J)	Selection scheme 1				2				3				4			
	DP_J[b]	$CDP1_J$[c]	CDP_J[d]	CDG_J[e]	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J
0 (calf)	-	-	-	376	0	0	0	0	0	0	0	0	0	0	0	0
1	0	376	376	376	875	875	0	0	0	0	0	0	1657	1657	0	0
2	0	376	376	376	875	1325	390	190	0	0	0	0	0	904	904	561
3	0	376	376	376	925	1700	790	395	0	0	0	0	0	835	835	561
4	0	376	376	376	875	2225	1270	595	0	0	0	0	0	766	766	561
5	0	376	376	376	750	2525	1750	780	0	0	0	0	0	766	766	561
6	0	376	376	376	625	2650	2100	935	0	0	0	0	0	766	766	561
7	0	376	376	376	460	2750	2350	1045	0	0	0	0	0	766	766	561
8	0	376	376	376	360	2825	2550	1120	0	0	0	0	0	766	766	561
9	0	376	376	376	310	2875	2700	1170	0	0	0	0	0	766	766	561
10	0	376	376	376	210	2925	2800	1220	0	0	0	0	0	766	766	561

[a]All parameters are expressed on a ME basis. These four selection parameters are constant for all periods.

[b]DP_J = the phenotypic result in lactation J of selection made in lactation J (the selection differential in terms of lactation J for selection made in lactation J).

[c]$CDP1_J$ = the phenotypic result in lactation J of all selection made through lactation J.

[d]CDP_J = the phenotypic result in lactation J of all selection made through lactation J-1.

[e]CDG_J = the genotypic result of selection made through lactation J-1.

Table 9. Phenotypic and genotypic selection parameters[a]: 120-cow herd, high-production level

Lactation (J)	Selection scheme 1				2				3				4			
	DP_J[b]	$CDP1_J$[c]	CDP_J[d]	CDG_J[e]	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J	DP_J	$CDP1_J$	CDP_J	CDG_J
0 (calf)	-	-	-	393	0	0	0	0	0	0	0	0	0	0	0	0
1	0	393	393	393	925	925	0	0	0	0	0	0	1722	1722	0	0
2	0	393	393	393	925	1375	0	0	0	0	0	0	0	939	939	583
3	0	393	393	393	950	1800	820	400	0	0	0	0	0	867	867	583
4	0	393	393	393	900	2325	1310	605	0	0	0	0	0	796	796	583
5	0	393	393	393	800	2650	1800	800	0	0	0	0	0	796	796	583
6	0	393	393	393	625	2800	2150	960	0	0	0	0	0	796	796	583
7	0	393	393	393	480	2900	2400	1070	0	0	0	0	0	796	796	583
8	0	393	393	393	380	3000	2600	1145	0	0	0	0	0	796	796	583
9	0	393	393	393	330	3050	2750	1195	0	0	0	0	0	796	796	583
10	0	393	393	393	230	3100	2850	1245	0	0	0	0	0	796	796	583

[a]All parameters are expressed on a ME basis. These four selection parameters are constant for all periods.

[b]DP_J = the phenotypic result in lactation J of selection made in lactation J (the selection differential in terms of lactation J for selection made in lactation J).

[c]$CDP1_J$ = the phenotypic result in lactation J of all selection made through lactation J.

[d]CDP_J = the phenotypic result in lactation J of all selection made through lactation J-1.

[e]CDG_J = the genotypic result of selection made through lactation J-1.

Selection parameters for selection system two Selection scheme two does not lend itself to easy, straight forward calculation of the selection parameters. Since selection takes place at each lactation, there is a continued reduction in the genotypic and phenotypic variances, and the distribution of the lactation production of the survivors is skewed. Formulae for calculating the reduction in the variances and the change in the covariances after one selection have been developed and were presented by Cochran (1951). For cases with more than one selection, these formulae would be based on the multivariate normal distribution and because of their complexity they have not been procedurely specified. Also, after one or more selections, the distribution of survivors becomes skewed and accurate selection intensities cannot be obtained by dividing the ordinate of the normal distribution at the point of truncation by the percent saved. Because of these limitations, the necessary parameters for selection scheme two were obtained from the results of a simulation procedure.

The following model was thought to sufficiently describe the record of a cow for this procedure:

$$P_{ij} = u + G_i + EP_i + ET_{ij},$$

where,

P_{ij} = the milk produced in the j^{th} lactation by the i^{th} cow,

u = the mean of the unselected population,

G_i = the genetic effect of the i^{th} cow,

EP_i = the effect of the environment which is permanent to all lactations of the i^{th} cow,

ET_{ij} = the temporary environment effect of the j^{th} lactation of the i^{th} cow. The temporary environmental effects of different lactations of the same cow are correlated,

$$\sigma_P^2 = \sigma_G^2 + \sigma_{EP}^2 + \sigma_{ET}^2, \qquad \mathrm{Cov}\ (P_{ij}, P_{ij'}) = r_{ij'}\sigma_P^2,$$

$$\sigma_P = 2500., \ \frac{\sigma_G^2}{\sigma_P^2} = 0.20, \ \frac{\sigma_{EP}^2}{\sigma_P^2} = 0.15, \ \frac{\sigma_{ET}^2}{\sigma_P^2} = 0.65,$$

$r_{jj'}$ = the correlation between the j and j' record (repeatability). The $r_{jj'}$ was used to incorporate in to the procedure unequal repeatabilities between different lactations. The values of the remaining parameters are given in Table 1.

Procedurely the lactations of a cow were generated in the following manner:

$$P_{ij} = u + \sigma_G R_{11} + \sigma_{EP} R_{12} + \sum_{k=1}^{j} \lambda_{kj} R_k, \qquad j = 1, 2, \ldots, 10, \quad k = 1, \ldots, j,$$

where, R_k = the k^{th} random number. Twelve new random numbers were chosen for each cow, the random numbers were normally distributed (0,1),

λ_{kj}^2 = the additional sum of squares of ET_j explained by ET_k.

A 10-square variance-covariance matrix of the ET's was set up. All diagonal elements (variances) were equal to .65 σ_P^2, and the off diagonals (covariances) were equal to $(r_{k,k'} - 0.35) x \sigma_P^2$. This matrix contained all of the left hand sides (LHS) of the equations needed to compute all of the λ^2. The corresponding right hand sides (RHS) for these equations were equivalent to the j^{th} column of the LHS.

The following model may be helpful to follow the procedure used:

$$ET_j = \sum_{k=1}^{j} B_k ET_k$$

For j = 10, lactation 10, the full set of equations given above were used with the RHS equal to the tenth column. The $\lambda_{k,10}$s were obtained as the difference in the sum of squares when the last row and column of the LHS and the last element of the RHS were successively dropped, i.e., $\lambda_{10,10} = R(B_1 \ldots. B_{10}) - R(B_1 \ldots. B_9)$. The λ's for the other j's were obtained by dropping the last 10 - j rows and columns from the LHS and the last 10 - j elements from the j^{th} column (RHS) and repeating the procedures described for j = 10. The number of resulting λ's was of triangular form:

$$\lambda^2_{1,1}, \lambda^2_{1,2}, \lambda^2_{2,2}, \ldots, \lambda^2_{10,7}, \lambda^2_{10,8}, \lambda^2_{10,9}, \lambda^2_{10,10}.$$

The objective of this simulation procedure was only to calculate the genotypic and phenotypic parameters needed (DP_J, $CDP1_J$, CDP_J, and CDG_J) for selection system two. The same set of parameters was used for all periods. Thus, a continuous 20-period selection with cows of all ages was not felt to be necessary. The number to be culled in each lactation in system two was established by trial and error, for combinations that would give the appropriate number of cow periods and that would give approximately 200 pounds of genetic gain per lactation. A proportion similar to the proportion actually culled in system two (Tables 15-20) for each herd size and production level was culled in the simulation procedure. The differences in the two proportions result from only whole cows being culled in the simulation procedure while fractional cows were culled in the actual system. Also, rather than generating only the number of two-year-old cows that were used for each herd size, 100 two-year-old cows were generated for each replicate of herd size and production level. The larger number of two-year-old cows were generated in the simulation procedure to minimize the difference, simulation vs. actual, in the proportion culled in each lactation.

The simulation and selection procedures are described below. Ten records each were generated for the 100 cows as described above. The number of cows to be culled involuntarily and voluntarily in each lactation were ascertained for each herd size and production level as previously described and were supplied to the program. Those to be lost involuntarily in each lactation were chosen at random from the cows available. This random process used a uniformly distributed random number between zero and one times the number available to obtain the animal to be culled. The remaining individuals were ordered on the average of their records through that lactation and truncation selection was applied. Both processes were repeated for each of the lactations. No animal already culled was available for the next stage of selection.

Sixty replicates of 100 cows were completed for the culling proportions for each of the six herds. The estimates of the needed parameters from each replicate of the simulation procedure were obtained. The average of these parameters over the 60 replicates is given in Table 10. These results from the simulation procedure were then subjectively adjusted to account for the difference between the proportion culled in the simulation procedure and the proportion actually culled in system two (Tables 15-20). These adjusted estimates for system two are given in Tables 4 through 9.

Table 11 was prepared to demonstrate the biases that would have been introduced if the standard normal approximations had been used for system two. The quantity $V(\text{mean})_e^{1/2}$, is the expected standard deviation of the mean with no selection, $V(\text{mean})_a^{1/2}$ is the actual standard deviation (from simulation) of the mean of the animals available for selection at each

Table 10. Parameters of selection for selection system two derived from the simulation procedure[a]

Selection parameters	Lactation 1	2	3	4	5	6	7
				40-cow herd			
	Low-production level						
DP	910.75	906.86	962.31	949.61	901.19	558.50	820.88
CDP	0.00	420.71	806.75	1340.06	1727.23	2048.74	2048.50
CDP1	892.77	1347.44	1768.25	2281.49	2681.43	2546.90	3208.25
CDG	0.00	171.95	369.80	578.27	774.56	965.13	1040.93
	Medium-production level						
DP	928.48	942.06	961.08	918.18	750.44	775.99	1030.58
CDP	0.00	431.40	862.40	1343.37	1815.20	2365.57	2303.63
CDP1	935.83	1356.51	1812.70	2304.87	2621.59	3073.26	3276.97
CDG	0.00	192.44	390.59	592.16	826.32	940.84	1061.33
	High-production level						
DP	974.80	1032.66	994.06	921.96	918.02	610.59	699.31
CDP	0.00	445.79	911.68	1376.94	1807.88	2422.80	2484.67
CDP1	980.91	1488.50	1874.83	2370.77	2840.44	2978.79	3331.24
CDG	0.00	212.82	436.24	654.89	851.46	1013.12	1155.06
				120-cow herd			
	Low-production level						
DP	777.89	868.90	861.22	898.16	852.09	623.27	2229.10
CDP	0.00	377.08	771.37	1142.65	1612.14	1924.45	996.53
CDP1	776.61	1233.78	1647.52	2096.00	2434.68	2515.50	2067.43
CDG	0.00	167.00	361.44	571.93	750.93	872.47	1060.21
	Medium-production level						
DP	864.91	906.30	953.88	900.11	740.67	758.41	1016.29
CDP	0.00	403.94	873.46	1319.08	1733.36	2018.05	2456.33
CDP1	844.58	1329.59	1830.61	2227.29	2526.61	2760.11	3594.11
CDG	0.00	172.43	383.25	570.27	742.67	914.41	1090.96
	High-production level						
DP	923.73	963.23	1022.15	979.23	726.46	855.23	866.33
CDP	0.00	414.73	881.54	1334.42	2061.59	2228.13	2931.09
CDP1	936.21	1372.92	1951.20	2304.85	2825.18	3117.66	3789.13
CDG	0.00	187.88	405.27	627.39	836.21	1010.76	1212.32

[a]These results are in terms of ME milk.

Table 11. Comparison of the actual means and variances from the simulation procedure with the standard normal approximations

Quantity	Lactation 1	2	3	4	5	6	7
1. $V(\text{mean})_e^{1/2}$	2500	2128	1989	1916	1870	1840	1817
2. $V(\text{mean})_a^{1/2}$	2555	1804	1426	1192	1043	950	952
3. Proportion selected	19/90	17/62	12/37	7/20	3/10	2/5	1/2
4. i	.366	.459	.532	.570	.497	.644	.798
5. $i\ V(\text{mean})_e^{1/2}$	915	976	1058	1092	1065	1184	1449
6. $i\ V(\text{mean})_a^{1/2}$	935	828	758	679	518	612	760
7. Actual selection[a] differential	923	785	710	611	426	475	472
8. h^2_{mean}	.200	.276	.316	.340	.357	.369	.378
9. Expected gain $(h^2)\,i\ V(\text{mean})_e^{1/2}$	183	269	334	371	380	437	548
10. Expected gain (actual selection[a] differential)	185	217	224	207	152	175	178
11. Actual genetic gain[a]	188	217	222	208	174	201	224

[a]From simulation.

lactation, and i is the standardized selection differential (the ordinate of the normal distribution at the truncation point divided by the percent saved). For the case of a single truncation of a normally distributed variable, formulae are available to predict the reduction in variance. However, the survivors of truncation selection are no longer normally distributed, thus, the formula does not apply to multi-step selections. The amount that the distribution is skewed is dependent upon the intensity of selection. Rows five, six and seven in Table 11 are the selection differentials calculated from the intensity and the expected standard deviation, the intensity and the actual standard deviation, and the actual selection differentials. The difference between the actual selection differential and the selection differential calculated from the expected standard deviation increases with each succeeding step of selection. Using the actual standard deviation, however, does not remove all of the difference. This remaining difference is due to i not being an appropriate estimate of intensity of selection for the skewed distribution. It has been suggested that the skewedness of the distribution with low to moderate culling is less critical than the reduction in variance. These data bear this out.

Age distribution and involuntary losses One necessary part of evaluating each of the selection systems is to determine the rate of involuntary losses from the herd. This process is made difficult by the myriad of reasons for which cows are culled and by the lack of data compiled in a way which would facilitate this calculation. However, several studies provide some basis for this decision. Miller et al. (1967) summarized the average herd life for 10 production levels. Production level was based on deviations from herdmates. The difference between the high and low decile ranged from 0.34 lactations for cows that had an opportunity to have two lactations to 1.63 lactations for cows that had an opportunity to have 10 lactations. Cows with an opportunity to have 10 lactations averaged 3.42 lactations, while the top decile with the similar opportunity averaged 4.02 and the low decile averaged 2.39 lactations.

Andrus (1968), using only cows which had the opportunity to have eight lactations, calculated, for 20 production levels, the percent of the cows which had each number of lactations. Production level in this study was measured as 305-day ME two-year-old production. The regrouped results of this study are presented in Table 12. The same trends seen by Miller _et al._ (1967) were also found by Andrus. The lack of cows in latter lactations, however, should be noted. This difference has been seen when the Iowa data have been compared with most age distributions from other areas. It may be concluded that Iowa cows are not kept to as old an age as cows in other areas.

Specht and McGilliard (1960) calculated the following culling information from Michigan DHIA data.

Reason for culling	Lactation number								
	1	2	3	4	5	6	7	8	9
Voluntary culls*	18.6	18.4	16.3	15.5	16.1	14.8	19.2	23.2	23.4
Involuntary culls*	6.6	8.9	10.0	13.0	15.8	21.2	21.7	31.0	26.1
Total culls*	25.2	27.2	26.2	28.5	31.9	36.0	40.9	54.2	49.5

*Expressed as a percent of the total number that started that lactation.

Involuntary culls (adjusted)**	8.1	10.9	11.9	15.4	18.8	24.9	26.9	40.4	34.1

**Expressed as a percent of the total number that started that lactation. The involuntary losses were adjusted for the cows culled voluntarily that would have been lost for involuntary reasons if they had remained in the herd. (adjusted by the author)

Specht and McGilliard, based on the above data, suggested that under Michigan conditions one-tenth were lost for involuntary reasons in each of the first three lactations and one-fourth were involuntarily culled thereafter. Rendel and Robertson (1950) suggested that natural mortality of dairy cows would remove one-sixth of the cows in the first three lactations and one-third in all subsequent lactations.

Table 12. Number of officially tested Iowa Holsteins calving for the first time in 1959 and the percentage having more than one lactation, by first lactation 305-day ME milk-production levels

Production levels	Number	Percent of first lactation cows having the following numbers of lactations						
		2	3	4	5	6	7	8
14,950 and above	621	81.00	64.41	46.05	32.21	20.13	9.02	1.13
13,190 - 14,949	686	75.97	51.89	35.99	25.51	14.42	5.69	0.44
11,890 - 13,189	594	71.20	48.16	32.00	20.37	11.65	4.69	0.84
10,180 - 11,889	669	69.69	40.54	23.18	13.89	9.26	4.47	0.75
Less than 10,179	663	54.03	27.45	16.88	11.02	6.38	3.62	0.45
Total and means	3233	70.30	46.20	30.60	20.50	12.40	5.50	0.71

In the California study of Gurtle and Smith[1], 40 percent of the culling was for production. It seems very possible that the majority of this selection was done at the early ages. It is possible to hypothesize that dairymen are more cognizant of the real depreciation costs in areas like California where many cows are purchased rather than raised. This could be one reason why cows are kept to older ages. In the data of Andrus (1968) and Miller et al. (1967) there should be little culling for low production in the top 20 percent production bracket. However, because first lactation production is not a perfect estimator of later production and because of the smaller herd size in these areas, some culling may be done for more personal reasons such as type. The research cited above was subjectively combined to derive involuntary losses for each lactation and these were used to form the age distributions used in this work. The percentages that were derived are given in Table 13.

Table 13. Percent of the cows starting each lactation which are lost for involuntary reasons during the lactation[a]

	Lactation									
	1	2	3	4	5	6	7	8	9	10
Percent lost involuntarily	10	13	17	20	25	30	40	60	70	100

[a]Same for all herd sizes and production levels.

[1]Gurtle, G. G. and F. F. Smith, Farm and Home Advisors Office, County Civic Center, Visalia, California. Summary of herd culling study, Orange and Los Angeles Counties (1968-1969). Private communication. 1970.

To calculate the age distributions for each of the culling schemes and herd-level groups, several formulae were developed. (Similar but less general formulae have been used by Touchberry (1970).) These formulae were developed with the following assumptions: a 13-month year, all cows that leave the herd average five months of production, and an even calving schedule. The percent of heifer calves born that enter the milking herd are given in Table 14. Data from Michigan and Illinois have demonstrated

Table 14. Percent of heifer calves born that enter the milking herd

	40-cow herd			120-cow herd		
Production level:	Low	Medium	High	Low	Medium	High
Born alive	94	95	96	93	94	95
Alive at 6 months	87	89	91	83	85	86
Alive at 1 year	84	86	88	80	82	84
Successfully bred	75	77	79	72	74	76
Freshen[a]	74	76	78	71	73	75

[a]Of those heifers born, the percent in the last line of the table will freshen if there is no voluntary culling.

that calf mortality decreases with an increasing level of production and with a decrease in herd size.

Because of the effect of rounding on the small number per age group, particularly in the 40-cow herd, fractional numbers at each age were used but the total number of cow months was held constant for each herd size. Using fractional cows appears to be equivalent to looking at these test herds as representing the average of many such herds. This seemed to be a better test of the culling schemes across levels of herd size than would be possible with alternative methods.

Equations used:

The number in lactation J + 1 = $N_{J+1} = N_J(1 - V_J)\ UN_J$,

Total cow periods (herd size) = CP = $N_1\left(\sum_{J=1}^{10} \prod_{I=1}^{J} UN_I\ (1 - V_I) + \right.$ (fraction of the lactation completed before the cow was culled = 5/13)),

Total number of cows that freshen in the period = NT = $\sum_{J=1}^{10} N_J$,

Number of first calf heifers available to enter the herd = $N_1(1 + \sum_{J=1}^{10} \prod_{I=1}^{J} UN_I(1 - V_I)(0.5)RP_K(1 - VO))$.

Definition of terms:

RP_K = percent of the heifer calves born that freshen for the K^{th} herd size - production level (Table 14),

UN_J = percent surviving to lactation J + 1 from lactation J with no voluntary culling (Table 13),

V_J = percent of those available for culling that were voluntarily culled during lactation J,

N_J = number starting the J^{th} lactation,

VO = the number of calves culled voluntarily,

NT = total number of different cows in the herd in the year,

CP = cow periods in the herd (herd size).

The V_J, VO, and the N_J for each of the culling schemes, herd size, and production levels are found in Tables 15 through 20. These figures for each herd size, production level, and selection system were derived from various

Table 15. The number starting each lactation and the percent voluntarily culled from each selection system: 40-cow herd, low-production level

Lactation J	Selection scheme 1	2	3	4
	Number starting lactation J			
1	9.64	19.16	19.16	19.16
2	8.68	13.69	17.25	7.80
3	7.55	8.74	15.00	6.79
4	6.27	5.04	0.38	5.63
5	5.01	2.72	0.00	4.51
6	3.76	1.37	0.00	3.38
7	2.63	0.67	0.00	2.37
8	1.58	0.29	0.00	1.42
9	0.63	0.09	0.00	0.57
10	0.19	0.02	0.00	0.17
	Proportion voluntarily culled from lactation J			
0 (calf)	0.43	0.00	0.00	0.00
1	0.00	0.21	0.00	0.55
2	0.00	0.27	0.00	0.00
3	0.00	0.31	0.97	0.00
4	0.00	0.33	1.00	0.00
5	0.00	0.33	0.00	0.00
6	0.00	0.31	0.00	0.00
7	0.00	0.27	0.00	0.00
8	0.00	0.21	0.00	0.00
9	0.00	0.13	0.00	0.00
10	0.00	0.03	0.00	0.00

Table 16. The number starting each lactation and the percent voluntarily culled from each selection system: 40-cow herd, medium-production level

	Selection scheme			
Lactation J	1	2	3	4
	Number starting lactation J			
1	9.64	19.80	19.84	19.84
2	8.68	13.90	17.86	7.74
3	7.55	8.71	14.51	6.73
4	6.27	4.91	0.00	5.59
5	5.01	2.60	0.00	4.47
6	3.76	1.28	0.00	3.35
7	2.63	0.61	0.00	2.35
8	1.58	0.26	0.00	1.41
9	0.63	0.08	0.00	0.56
10	0.19	0.02	0.00	0.17
	Proportion voluntarily culled from lactation J			
0 (calf)	0.45	0.00	0.00	0.00
1	0.00	0.22	0.00	0.57
2	0.00	0.28	0.07	0.00
3	0.00	0.32	1.00	0.00
4	0.00	0.34	0.00	0.00
5	0.00	0.34	0.00	0.00
6	0.00	0.32	0.00	0.00
7	0.00	0.28	0.00	0.00
8	0.00	0.22	0.00	0.00
9	0.00	0.14	0.00	0.00
10	0.00	0.04	0.00	0.00

Table 17. The number starting each lactation and the percent voluntarily culled from each selection system: 40-cow herd, high-production level

	Selection scheme			
Lactation J	1	2	3	4
	Number starting lactation J			
1	9.64	20.51	20.53	20.53
2	8.68	14.12	18.47	7.68
3	7.55	8.66	13.63	6.68
4	6.27	4.78	0.00	5.54
5	5.01	2.47	0.00	4.43
6	3.76	1.19	0.00	3.33
7	2.63	0.56	0.00	2.33
8	1.58	0.24	0.00	1.40
9	0.63	0.07	0.00	0.56
10	0.19	0.02	0.00	0.17
	Proportion voluntarily culled from lactation J			
0 (calf)	0.46	0.00	0.00	0.00
1	0.00	0.24	0.00	0.58
2	0.00	0.30	0.15	0.00
3	0.00	0.34	1.00	0.00
4	0.00	0.36	0.00	0.00
5	0.00	0.36	0.00	0.00
6	0.00	0.34	0.00	0.00
7	0.00	0.30	0.00	0.00
8	0.00	0.24	0.00	0.00
9	0.00	0.16	0.00	0.00
10	0.00	0.06	0.00	0.00

Table 18. The number starting each lactation and the percent voluntarily culled from each selection system: 120-cow herd, low-production level

	Selection scheme			
Lactation J	1	2	3	4
	Number starting lactation J			
1	28.92	54.39	54.51	54.51
2	26.03	39.99	49.06	23.68
3	22.65	26.34	42.68	20.60
4	18.80	15.67	7.31	17.10
5	15.04	8.74	0.00	13.68
6	11.28	4.57	0.00	10.26
7	7.89	2.29	0.00	7.18
8	4.74	1.04	0.00	4.31
9	1.89	0.34	0.00	1.72
10	0.57	0.09	0.00	0.52
	Proportion voluntarily culled from lactation J			
0 (calf)	0.41	0.00	0.00	0.00
1	0.00	0.18	0.00	0.52
2	0.00	0.24	0.00	0.00
3	0.00	0.28	0.79	0.00
4	0.00	0.30	1.00	0.00
5	0.00	0.30	0.00	0.00
6	0.00	0.28	0.00	0.00
7	0.00	0.24	0.00	0.00
8	0.00	0.18	0.00	0.00
9	0.00	0.10	0.00	0.00
10	0.00	0.00	0.00	0.00

Table 19. The number starting each lactation and the percent voluntarily culled from each selection system: 120-cow herd, medium-production level

	Selection scheme			
Lactation J	1	2	3	4
	Number staring lactation J			
1	28.92	56.38	56.49	56.49
2	26.03	40.70	50.84	23.49
3	22.65	26.27	44.23	20.44
4	18.80	15.31	3.21	16.97
5	15.04	8.35	0.00	13.57
6	11.28	4.27	0.00	10.18
7	7.89	2.10	0.00	7.13
8	4.74	0.93	0.00	4.28
9	1.89	0.30	0.00	1.71
10	0.57	0.08	0.00	0.51
	Proportion voluntarily culled from lactation J			
0 (calf)	0.42	0.00	0.00	0.00
1	0.00	0.20	0.00	0.54
2	0.00	0.26	0.00	0.00
3	0.00	0.30	0.91	0.00
4	0.00	0.32	1.00	0.00
5	0.00	0.32	0.00	0.00
6	0.00	0.30	0.00	0.00
7	0.00	0.26	0.00	0.00
8	0.00	0.20	0.00	0.00
9	0.00	0.12	0.00	0.00
10	0.00	0.02	0.00	0.00

Table 20. The number starting each lactation and the percent voluntarily culled from each selection system: 120-cow herd, high-production level

Lactation J	Selection scheme 1	2	3	4
	Number starting lactation J			
1	28.92	58.43	58.50	58.50
2	26.03	41.39	52.65	23.31
3	22.65	26.18	44.85	20.28
4	18.18	14.93	0.00	16.83
5	15.04	7.96	0.00	13.47
6	11.28	3.98	0.00	10.10
7	7.89	1.92	0.00	7.07
8	4.74	0.84	0.00	4.24
9	1.89	0.26	0.00	1.70
10	0.57	0.07	0.00	0.51
	Proportion voluntarily culled from lactation J			
0 (calf)	0.44	0.00	0.00	0.00
1	0.00	0.21	0.00	0.56
2	0.00	0.27	0.02	0.00
3	0.00	0.31	1.00	0.00
4	0.00	0.33	0.00	0.00
5	0.00	0.33	0.00	0.00
6	0.00	0.31	0.00	0.00
7	0.00	0.27	0.00	0.00
8	0.00	0.21	0.00	0.00
9	0.00	0.13	0.00	0.00
10	0.00	0.03	0.00	0.00

combinations of the above equations and the percents surviving from Tables 13 and 14.

Since not all herds operate under the same physical and economic situations, each of the cow selection systems was evaluated for different levels of the following factors: sire selection, herd size and production level, replacement costs (and consequently cow depreciation), feed costs, and milk price.

Sire selection systems

Both because of the different types of sire selection available (different studs, and different sires within studs), and because of the effect of the rate of genetic gain in the sires on the different cow selection systems, three different sire selection schemes were evaluated. Sire selection systems one and two used different sires within the same stud (population), while sire system three started at the same point as sire system two, but progressed at the rate of two percent of the initial mean per year. The stud from which the sires in systems one and two came, should be making genetic progress equivalent to the more progressive studs now functioning, approximately one percent of the initial mean per year.

Basic parameters of the stud (systems one and two):

The cow population serviced from this stud has 750,000 cows,

The stud is made up of 50 progeny tested bulls,

52 bulls are tested each year,

12 progeny tested bulls must be produced each year to replace those lost involuntarily from the proven stud. (34 of the 52 young bulls survive to the completion of the progeny test),

Progeny tested bulls were mated to 2½ percent of the cow population.

All of the cows used for progeny testing were milk recorded.

The cow population had the following age distribution and cumulative genetic gain due to between-cow selection:

Age	Percent of the total herd	Cumulative genetic gain
2	27.98	0.00
3	22.62	50.00
4	16.94	100.00
5	12.50	150.00
6	8.47	200.00
7	5.30	225.00
8	3.07	250.00
9	1.65	250.00
10	1.10	250.00
11	0.37	250.00

The sires used to produce young bulls were the top 15 percent of the bulls in the proven stud the year the insemination (special mating) was made.

$\bar{i} = 1.55$, $R_{IH} = 0.8$

$$\Delta G_S = \bar{i} R_{IG} \sigma_G$$
$$= (1.55)(0.8)(1118)$$
$$= 1386(\text{ME}),\ 1083(\text{HE})$$

The dams used to produce young bulls were the top 20 percent of the cows in second or later lactation in the population. $\bar{i} = 1.40$, $R_{IH} = 0.65$

$$\Delta G_D = \bar{i} R_{IG} \sigma_G$$
$$= (1.44)(0.65)(1118)$$

$$= 1046(ME),\ 817(HE)$$

The bull calves produced from their matings had breeding values 1216 pounds ME or 950 pounds HE basis above the parent population and had an $R_{IG} =$ 0.52. The top 35 percent of the progeny test bulls that survived to the end of the test were selected to enter the proven stud. $\bar{i} = 1.036$, $R^2_{IH} = 0.59$

$$\Delta G_{PT} = \bar{i}R'_{I_2G}\sigma_G'$$

$$= (1.036)(0.729)(988)$$

$$= 746 \text{ (ME basis)}$$

$$= 583 \text{ (HE basis)}$$

$$\sigma_G' = \sigma_G \sqrt{1-R^2_{I_1G}(1-\sigma_s)}$$

$$= 1118 \sqrt{1-(.52)^2(1.-0.2)}$$

$$= 988$$

$$R'_{I_2G} = R_{I_2G}\sqrt{\frac{1-R^2_{I_1G}(1-\sigma_s)}{1-R^2_{I_1G}R^2_{I_2G}(1-\sigma_s)}}$$

$$= .769 \sqrt{\frac{1-(.270)(.8)}{1-(.270)(.59)(.8)}}$$

$$= .729$$

σ_G' and R'_{I_2G} are the standard deviation of breeding values among the group saved in the first culling and the multiple correlations of breeding value with the criterion of selection for the first and second culling among animals retained in the first culling, respectively. σ^2_s is the fraction of the original variance of I_1 that remains in the selected group.

While these selection differentials are not what the more optimistic observers would suggest, they are probably at least as good as the best stud is doing at the present time. Also, this purposely allows for enough selection for milk fat to hold fat percent constant at 3.5 percent.

Similar parameters for the sires were:

Age	Percent of the total services	Cumulative genetic gain
1	2.50	950.00
2	0.00	0.00
3	0.00	0.00
4	0.00	0.00
5	23.40	1533.00
6	19.50	1533.00
7	15.60	1533.00
8	13.65	1533.00
9	9.75	1533.00
10	7.80	1533.00
11	5.85	1533.00
12	1.95	1533.00

<u>Sire system one</u> The sires used in this system were those available in period I that had survived the selection on progeny test information in that year. Since no further voluntary selection was practiced, this was the <u>group</u> of sires with the highest breeding value in the stud.

<u>Sire system two</u> The sires included in this system were intended to approximate breed-average sires. Thus, their breeding value (GB_I) was set equal to the genetic level in period I of all of the two-year-olds produced

from the stud described previously. The difference between the sires in group one and group two in any year was 1004 (HE) pounds of milk. However, since both groups came from the same stud they both improved at the same rate genetically.

Sire system three The sires in group three were intended to approximate the best (fastest genetic gain) system thought to be possible at this time. Several estimates have been made of the amount of genetic progress that is possible in dairy cattle (Robertson and Rendel, 1950; Hunt et al., 1970; Thomson, 1968). Most of these estimates of maximum rate of progress were near two percent of the mean per year. While this may be slightly more optimistic than realistic, it would appear that this goal is possible, but expensive.

Herd size and production level

Two of the most important factors affecting income and costs are herd size and production level. It is also evident that the per-cow cost and income are not constant for different levels of these two factors. Two herd sizes and three levels of production for each of the herd sizes were evaluated. The two herd sizes chosen were 40 cows and 120 cows. The average size of the dairy herds on test in Iowa at the present time is slightly less than 40 cows. Thus, the smaller of the two herd sizes is in the range of this average. While there is some justification for a still smaller herd size, one was not evaluated because of the general trend in herd size, and because many of the herds with less than 40 cows do not have dairy as main farming operation. The larger herd size of 120 cows was chosen to be large enough to be different from the 40 cow herd while still being small enough to provide information to the majority of large herds functioning in the Midwest in the near future. The possibility of evaluating a larger herd (300 cow periods) was considered, but decided against because of the lack of information on the physical and economical relationships under Midwest conditions and because of the limited use of the results of this level of the factor in the near future.

The production levels chosen, like the herd sizes, tend to be the upper side of what is now being accomplished in the Midwest. The levels are given in Table 21. The lower level chosen, 11,500 lbs./cow/305 days (ME) is approximately 1,500 lbs. below the 13,000 lbs. of all Holsteins on test (305, 2X, ME), while the middle level is 1,000 lbs. above the average, and the higher level is 3,500 lbs. above average. There are, however, many herds within the state which are producing at each of these levels. The genetic levels for the three production levels were set assuming that between 10 and 15 percent of the phenotypic differences between herd averages are genetic.

Table 21. Beginning levels of genetic and phenotypic production for each of the production levels

Production level	Phenotypic level		Genetic level	
	Mature equivalent	Heifer equivalent	Mature equivalent	Heifer equivalent
Low	11,500	8,984	13,700	10,703
Medium	14,000	10,938	14,000	10,938
High	16,500	12,890	14,300	11,172

It was necessary to obtain the fixed and variable costs associated with each of the production levels and herd sizes. The amount of available information regarding these costs on Iowa dairy operations is very limited. This is partially because dairy operations in Iowa are economically less important than several of the other agricultural commodities. Milk is still a very important commodity in Iowa, especially when it is compared to the dairy industry in most other states. Because of this lack of information, bulletins and other materials from other states were also evaluated and adjusted in preparing the fixed and variable costs which are found in Tables 22, 23, and 24. The purposes of these budgets were to present costs that were not varied in the study, and second to give the reader an idea of the total production costs.

Two studies of the economic inputs of the dairy operation were extremely helpful in providing a format of what needed to be included. Shultis, Forker, and Appleman (1963) prepared budgets for three phases of a specialized dairy operation in California. They considered the heifer raising, forage producing, and the milking herd separately. While the economic costs that they supplied were specific for California almost 10 years ago, they did provide an excellent outline of the costs that needed to be considered. In a more recent bulletin, Saunders et al. (1970) completed an economic analysis of four alternative dry-lot feeding systems for lactating dairy cows. The feed costs that they reported were from a planned experiment in Georgia. The amounts and the composition of the feeds that they used combined to form extremely high energy requirements per pound of milk. The other fixed and variable costs that they reported, however, appeared to be in line with other reports and were fairly complete. Thus, the costs

Table 22. Fixed costs per year for 120- and 40-cow dairy herds--calf rearing and feed production not included

Item	New investment	Interest 7%	Deprec.	Repair	Taxes & ins.
	40-cow dairy herd				
Cows @ $400/cow	$16,000	$---[a]	$---[a]	$---	$250
Buildings, yards and milking and $650/cow feeding facilities (25 years)	26,000	1060	865	260	435
Maternity barn	3,000	122	100	30	40
Truck	2,750	105	200	30	35
Small tractor	4,250	165	250	90	60
Feed wagon, loader	2,000	87	120	20	30
Total fixed costs		1539	1535	430	850
Total fixed costs					$4,354
	120-cow dairy herd				
Cows @ $400/cow	$48,000	$---[a]	$---[a]	$---	$750
Buildings, yards and milking and $500/cow feeding facilities (25 years)	60,000	2450	2000	600	1000
Maternity barn	5,000	197	175	50	70
Truck	4,000	140	300	60	50
Small tractor	5,000	185	275	125	70
Feed wagon, loader	2,500	90	170	30	35
Total fixed costs		3062	2920	865	1975
Total fixed costs					$8,822

[a]While there is real depreciation and interest it is handled on a cash basis.

Table 23. Total costs for a 40-cow dairy herd--12,000 lbs. milk/cow/year - actual

Item	Total cost		Cost/cwt milk	
Feed[a] @ $2/cwt milk	$9,600		$2.000	
*Labor @ 65 hours/cow ($2/hour)	5,200		1.083	
*D.H.I.	276		0.058	
Breeding fees[b] (10.00/first service)	450		0.094	
*Electricity	500		0.104	
*Fuel and oil	300		0.063	
*Veterinary and medicine (15.00/cow)	600		0.125	
*Dairy supplies	500		0.104	
*Workmens compensation, social security	425		0.089	
*Fixed costs	4,354		0.907	
*Miscellaneous	500		0.104	
Subtotal (* items)		12,655		2.636
Subtotal		22,705		4.730
Cow depreciation[c], 150/cow; 3 years, and interest	3,120		0.650	
Total		25,825		5.380

[a]The actual feed costs used in this study varied with the level of production, and the level of the cost of feed per Mcal NE_L. Intermediate values of these three items in the footnotes are included in this budget.

[b]The number of first services varied with the herd size and the selection system and the price per first service varied with the sire selection system.

[c]Cows depreciation varied with the selection system and the rearing cost and cow valuation varied with production level and rearing cost.

Table 24. Total costs for a 120-cow dairy herd--12,000 lbs. milk/cow/year - actual

Item	Total cost	Cost/cwt milk
Feed[a] @ $2/cwt milk	$28,800	$2.000
*Labor @ 45 hours/cow ($2/hour)	10,800	0.750
*D.H.I.	660	0.046
Breeding fees[b] (10.00/first service)	1,350	0.094
*Electricity	1,200	0.083
*Fuel and oil	900	0.063
*Veterinary and medicine (15.00/cow)	1,800	0.125
*Dairy supplies	1,200	0.083
*Workmens compensation, social security	850	0.059
*Fixed costs	8,822	0.613
*Miscellaneous	1,000	0.069
Subtotal (* items)	27,232	1.891
Subtotal	57,382	3.985
Cow depreciation[c], 150/cows; 3 years, and interest	9,360	0.650
Total	66,742	4.635

[a]The actual feed cost used in this study varied with the level of production, and the level of the cost of feed per Mcal NE_L. Intermediate values of these three items in the footnotes are included in this budget.

[b]The number of first services varied with the herd size and the selection system and the price per first service varied with the sire selection system.

[c]Cows depreciation varied with the selection system and the rearing cost and cow valuation varied with production level and rearing cost.

suggested in these two reports were used as the starting points in preparing the fixed and variable costs for herds of different sizes. There appear to be very few other reports where the economic parameters supplied refer to the dairy operation separate from other agricultural enterprises on the same farms. Prices and some of the physical constants needed in preparing the budget were obtained from records of the Iowa Dairy Breeding Herd, *Dairy Situation* (Nov., 1970), *Iowa Farm Science* (Feb., 1970), and other reporting agencies. The proposed budgets appear in Tables 23 and 24.

Rearing cost

There have been many published reports of rearing costs in the popular literature (*Big Farmer*, August 1970; *Big Farmer*, January 1970; Iowa Extension Dairymen, 1965; Stone and Barker, 1965; Lamb and Perkes, 1969; Frick and Henry, 1956). There was a wide variability in the physical inputs considered necessary to raise a heifer from birth to freshening. Some of the sources of this variability were: area of the country (housing needed, pasture available); amount of mechanization (replacement of machinery for labor); age and condition of heifers at freshening; and the completeness of "other costs" included. The variability in the unit prices of the physical inputs tended to further increase the variability in the estimates of total rearing costs. The estimates of the total cost of rearing in the reports from recent years ranged from less than \$200.00 to \$403.46. A breakdown of total rearing cost was obtained by subjectively combining the results of the reports cited previously in Tables 25 and 26. The total amounts of feed needed for the rearing period were compared with the results of various researchers. The amount of grain used in the two-year period was in

Table 25. Possible costs of raising a calf from birth to freshening

Age period	Itemized costs		Total costs		Additional cost for 28 months
0-2 months	Feed costs				
	Whole milk 56 @ 4.00/cwt	2.25			
	Milk replacer 32 @ 25.00/cwt	8.00			
	Concentrates 100 @ 3.75/cwt	3.75			
	Hay 40 lbs. @ 30.00/ton	.60			
			14.60		
	Labor 11 hours @ 2.00/hr.		22.00		
	Vet and vet supplies		3.00		
	Bedding		1.50		
	Buildings, pen and equip.		1.50		
	Miscellaneous, including interest		2.00		
				44.60	
3-6 months	Feed costs				
	Concentrates 550 @ 3.75/cwt	20.62			
	Hay 417 lbs. @ 28.00/ton	5.84			
			26.46		
	Labor 5 hours @ 2.00/hr.		10.00		
	Bedding		1.00		
	Misc., including int. & facilities		4.50		
				41.96	
7-12 months	Feed costs				
	Concentrates 480 @ 3.75/cwt	18.00			
	Hay 2479 lbs. @ 26.00/ton	32.23			
			50.23		
	Labor 5 hours @ 2.00/hr.		10.00		
	Misc., including int. & facilities		7.40		
				67.63	
13-24 months	Feed costs				
	Pasture (5 mo.) @ 5.00/mo.	25.00			
	Hay 2.5 tons @ 24.00/ton	60.00			40.00
	Concentrates 150 @ 3.50/cwt	5.25			2.00
			90.25		
	OR Corn silage 8.5 T. @ 9.00/ton		(76.50)		(33.00)
	Labor 8 hours @ 2.00/hr.		16.00		5.00
	Breeding		7.00		
	Miscellaneous: taxes, ins., etc.		8.00		
	Interest on investment		12.00		4.00
				133.25	
				(119.50)	
	Total costs				
	Hay only			287.44	338.44
	Hay and silage			(273.69)	(315.69)

Table 26. Summarization of costs of raising a calf from birth to freshening

Item	Total for 24 months		Average	Additional for 24-28 months	
	Amount	Cost($)	Cost/unit	Amount	Cost($)
<u>No corn silage</u>					
Whole milk	56 lbs.	2.25	4.00/cwt		
Milk replacer	32 lbs.	8.00	25.00/cwt		
Concentrates	1300 lbs.	47.62	3.66/cwt	58 lbs.	2.00
Hay	7936 lbs.	98.67	24.86/ton	3334 lbs.	40.00
Pasture	5 mo.	25.00	5/mo.		
Total feed costs		181.54			42.00
<u>Corn silage & hay</u>					
Whole milk	56 lbs.	2.25	4.00/cwt		
Milk replacer	50 lbs.	8.00	16.00/cwt		
Concentrates	1150 lbs.	42.37	3.68/cwt		
Hay	2936 lbs.	38.67	26.34/ton		
Corn silage	17000 lbs.	76.50	9.00/ton	7333 lbs.	33.00
Total feed costs		167.79			33.00
Labor	29 hrs.	58.00	$2.00/hr.	2.5 hrs.	5.00
Vet		3.00			
Bedding		2.50			
Breeding		7.00			
Misc: int., taxes, ins., buildings, etc.		35.40			4.00
Total other costs		105.90			9.00
Total (no silage)		287.44			338.44
Total (hay and corn silage)		273.69			315.69

very close agreement with the amount fed by Lamb and Perkes (1969) in Utah and with the older figures of Frick and Henry (1956) based on survey data in New England, but was slightly higher than the amount recommended by Stone and Barker (1965) in New York. The total forage feed from birth to calving was higher than that found by Frick and Henry but lower than the observed value of Lamb and Perkes and slightly lower than the New York values. The total forage feed was in agreement with the present feeding policy in the Iowa State Dairy Breeding Herd.

Based on the figures in Table 25, \$325 was chosen as an intermediate rearing cost. Two other levels for this factor were chosen at \$75 on either side of the intermediate level. The value of the heifer calf at birth was not included in this estimate. Only calves not kept for replacement purposes were credited as income to the dairy herd. The number of females entering the herd was multiplied times the appropriate rearing cost. This amount was included as an expense for each herd period. The pounds of beef from culled cows was multiplied times the beef price and was included as income to the herd, while feed used for growth (two- and three-year olds) was included as a cost. Thus, the actual value of the heifer entering the herd was the rearing cost plus the loss of income due to keeping the heifer calf (\$50.00). Similarly, the actual cow depreciation amounted to the total cost of the heifer entering the herd minus her salvage value divided by her herd life. If the cost of the feed needed for growth equaled the increased salvage value from two years of age until she left the herd, the actual depreciation would equal the cost of the heifer entering the herd minus her salvage value as a two-year-old cow (\$225). This would leave \$75, \$150, and \$225 to be depreciated over the life of the cow for each of the three rearing costs, respectively.

Price of feed

Feed costs are the main variable cost of producing milk. Two feed constituents exert a major influence on the total ration price. Protein has traditionally been the most expensive component of animal feeds. This results, at least in part, from the competition for protein sources by all animal species and man. Some energy sources, on the other hand, have been available at a lower price. Part of this price differential has been induced by the type of feeds which are high in the individual constituents. Roughages have generally been available at lower prices per unit than have concentrates and concentrates with a high energy content (corn, etc.) have been available at a lower per unit price than have concentrates with a high protein content. The use of non-protein nitrogen sources by the ruminant has the effect of lowering the price of protein in the ruminant ration. Because of the large quantity of protein and energy produced by the cow in early lactation, the ration for this period must have rather high quantities of protein and energy to minimize the negative balance of these factors. While energy may be in the greatest imbalance at this point, this imbalance is partially offset by the ability of the cow to use energy from body stores.

In this study, a simple, but accurate method of assessing feed costs to each herd was needed. The cost of a Mcal of NE_L of a ration which was balanced to provide adequate protein was used as the basis of the costing of feed. The maintenance, growth, pregnancy, and production requirements of Net Energy-Lactating Cows (NE_L) were calculated for cows producing at different levels of production. The ratio of the Mcal of NE_L per kg of Digestible Protein required ranged from 30.0 for dry cows to 16.5 for cows producing over 90 lbs. of milk per day. Over a wide range of production values this ratio ranged between 17 and 19. Thus, prices appropriate to a total ration within this range of the ratio were chosen to establish the medium price per Mcal of NE to be used for this study. It appears that, with Iowa prices of the past several years, \$0.033 per Mcal of NE_L would be appropriate for a ration using a large proportion of corn silage and with urea providing a part of the protein requirement. For a mature cow producing 12,500 lbs. of 3.5 percent milk, and having a 13 month calving interval, the feed cost per hundred pounds of milk would be \$2.23. This is over \$0.25 above the average of the feed costs reported for all of the Holstein cows on the Iowa DHIA program (1968). While this may reflect in part the increase in feed costs during the past two years, it also tends to reflect farmer under-pricing of feedstuffs on the DHI report. The lower limit chosen was \$0.024 per Mcal of NE_L. This price is probably closer to an absolute minimum for this factor than the lower levels of any of the other factors in the model. This comes about because of the homogeneity of the types of feed used in Iowa and the lower costs of dairy feeds which are all produced by the dairy farmer or at least in close proximity to him. The upper level of the factor was set at \$0.045. While this cost would not be high enough for certain areas outside of the Midwest, it is higher than the large majority of dairy farmers in the Midwest experience. Feed prices represent the total cost of production including ownership cost of the land and equipment. The following table (Table 27) gives the feed cost per hundred pounds of milk for a mature cow (1425 lbs.) with a 13 month calving

Table 27. Feed cost[a] per cwt of milk for a mature cow with a 13 month calving interval

Production level	Mcal NE needed		Price		
	Total	Mcal/cwt milk	$0.025/Mcal	$0.033/Mcal	$0.045/Mcal
10,000	7,685	76.85	1.84	2.54	3.46
12,500	8,470	67.76	1.62	2.34	3.05
15,000	9,255	61.70	1.48	2.03	2.78
17,500	10,040	57.37	1.38	1.89	2.58

[a]No upward adjustment has been made in these prices for the lowered digestibility at high levels of feed intake and the 3 percent wastage allowance has not been added here.

interval and producing at different levels. The average weights at five months into the lactation are given in Table 28.

Milk price

Milk price is the major economic variable in determining income from the dairy operation. The average price per 100 pounds of milk received by farmers in the United States has increased over $1.60 in the past 20 years. More than $1.20 of this increase has taken place in the past five years

Table 28. Weight five months into the lactation

	Lactation			
	1	2	3	4 and above
Weight	1175	1300	1375	1425

(Dairy Situation, November 1970). Several reasons would appear to be responsible for this change. During the later part of this 20-year period, the supply of milk has been declining slightly. This was the effect of the increasing price-cost squeeze, the increasing need for major improvements (bulk tanks, etc.), and the improving price paid for cull dairy cows. Inflation in the prices paid by dairy farmers for needed inputs has exerted a major influence on the price-cost squeeze. The enthusiastic work of existing marketing cooperatives and the formation of several large regional cooperatives have exerted political pressure to increase milk prices and have tended to give the producers a stronger position in determining the price of their product[1]. While it is almost impossible to predict what will happen to milk prices in the future, there seems to be some evidence that the forces mentioned above will hold milk prices at the current levels or above. Thus, the medium, net milk price was chosen at $5.50. The lower level of milk price was set at $5.00 and the higher price was set at $6.50. These prices for Grade A milk reflect nearly the entire range of prices experienced by the dairymen in most areas of the country.

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[1]Strain, J. R., Department of Economics, Iowa State University, Ames, Iowa. Discussion of the factors influencing milk pricing. Private communication. 1971.

RESULTS AND DISCUSSION

Two methods will be used to present the results of this study. All of the production and profit results will be given in tabular form in the appendix of the thesis. Also, graphical representation will be made of representative parts of each set of results to help see the trends that are taking place. Discussion of the results will proceed sequentially with the presentation of the results. This presentation will be divided into four sections: physical characterization of the herds and selection systems; genetic and phenotypic levels of milk production for each herd period; description of the economic variables for the different factors; and evaluation of several measures of profit.

Physical Characterization of the Herds

Herd-life and age characteristics

The herd-life and age characteristics for each selection system, herd size, and production level are presented in Table 29. The small differences between the herd size and production level combinations were due entirely to differences in the rearing success of the different groups. Selection system one can be visualized as establishing the oldest age distribution possible with the involuntary losses given in Table 13 and constant herd size. On the other hand, selection system three establishes the youngest age distribution possible for the same conditions. Neither allow for any voluntary culling of production-age cows.

Selection system one had an average of 4.8 calvings per cow, an average age at calving of 60.6 months and an average age when sold of 81.9

Table 29. Herd-life and age characteristics for selection scheme, herd size, and production level

Herd size	Production level	Cow selection scheme			
		1	2	3	4
		Average age at calving[a]			
40	Low	60.6	45.8	40.2	54.0
40	Medium	60.6	45.3	39.7	53.5
40	High	60.6	44.6	39.3	53.1
120	Low	60.6	46.8	41.2	54.6
120	Medium	60.6	46.2	40.5	54.2
120	High	60.6	45.5	39.9	53.8
		Average age when sold[a]			
40	Low	81.9	55.2	55.1	55.1
40	Medium	81.9	54.3	54.2	54.2
40	High	81.9	53.4	53.3	53.3
120	Low	81.9	56.7	56.6	56.6
120	Medium	81.9	55.7	55.6	55.6
120	High	81.9	54.7	54.7	54.7
		Average calvings per cow			
40	Low	4.8	2.7	2.7	2.7
40	Medium	4.8	2.6	2.6	2.6
40	High	4.8	2.6	2.6	2.6
120	Low	4.8	2.8	2.8	2.8
120	Medium	4.8	2.7	2.7	2.7
120	High	4.8	2.7	2.7	2.7
		Percent-days-in-milk			
40	Low	84.6	86.2	86.1	86.1
40	Medium	84.6	86.3	86.3	86.3
40	High	84.6	86.4	86.4	86.4
120	Low	84.6	86.0	86.0	86.0
120	Medium	84.6	86.1	86.1	86.1
120	High	84.6	86.2	86.2	86.2

[a]Age in months.

months. Selection systems two through four had nearly identical average calvings per cow of 2.7 and average age when sold of 55.2 months. The average ages when sold for cow systems three and four were different in the second decimal. However, the three systems varied in the average age at calving. In each of these selection systems within herd size and production level the number of two-year-old cows entering the herd was almost exactly the same (Tables 15-20). Thus, the selection system determined how long the cows would stay in the herd.

Selections in cow system two were made on the best ME average regardless of age, to the extent that herd size would be maintained. Selections in system three were made to keep the youngest herd possible, while as many two-year-old cows as would allow herd size to be maintained were culled in system four. In all three cases, all heifers that survived were raised and freshened. The number of calvings per cow necessary to maintain herd size when all heifers are freshened can be expressed as:

$$\frac{1}{\text{(percent of the calves born that are heifers)} \times \text{(the rearing success)}}.$$

As can be seen from Tables 15-20, this number of calvings per cow can be obtained with several rather different age distributions. However, the same forces that fix average calvings per cow also fix the average age when cows leave the herd. These figures would vary slightly with the average months of production before culling.

The average age at calving is the only age characteristic given which reflects the age distribution for the systems where all heifers were raised. As would be expected, system three has the lowest average age at calving, followed by systems two and four. This age parameter also reflects the proportion of the cows producing at the different ages, and thus, the corresponding production for a given genetic or phenotypic level. This will be discussed later in more detail.

Percent-days-in-milk

While there is no exact way to calculate percent days in milk in this study, a rough approximation can be obtained by:

$$\frac{(329)(\text{no. of cows that complete a lactation})+(152)(\text{no. of cows culled})}{(396)(\text{no. of cow periods})}.$$

The 396 is the number of days in a period and the number of cow periods is equal to the herd size. The 329 days of production is based on the 67 days dry average of all Holsteins on test (DHIA summary 1966-1967, Voelker *et al*., 1967). The percent of days in milk, calculated as described, were 84.6, 86.2, 86.1, and 86.1, respectively, for the 40 cow herd at the low production level. The corresponding figures for the other herd sizes and production levels are almost identical and are given in Table 29. The difference between system one and the other three systems is due to the smaller number of cows being culled from the herd in system one than in the other systems, since culled cows have 100 percent days-in-milk for that lactation. The percent days-in-milk calculated in the manner described in this paragraph should provide a reasonable comparison of the different selection systems, but would hardly give an adequate comparison across production levels. A summary of data from the 1967-1968 testing year of cows on DHIA test in Iowa (Voelker *et al*., 1968) shows a strong positive relationship between percent days in milk, cwt of concentrates fed, and the production level. While there is some confounding among these variables and with non-specified variables, one could suggest that percent days in milk and pounds of concentrates fed are two of the main non-genetic influences of production level and they are useful indicators of the management of the herd. The correspondence between <u>change</u> in these three factors has previously been shown by Stone *et al.* (1966). Thus, the comparison across production levels should probably include different days per lactation at the different levels of production. However, this comparison is not within the range of this study.

<u>The average effect of the age distribution on the actual production</u>

To help evaluate the genetic and phenotypic levels given in the next sub-section, the average percent of the two-year-old level was calculated as:

$$\frac{\sum_{J} \frac{FME_1}{FME_J} DNO_{K,J}}{\sum_{J} DNO_{K,J}}$$

where, FME_1 and FME_J are the appropriate mature equivalent factors for the first and the J^{th} lactation, and $DNO_{K,J}$ is the number calving in the J^{th} lactation in the K^{th} selection system. These values are presented in Table 30.

As in the other results given thus far, differences between herds of different size and production levels are due to the difference in rearing success. For cows of the same producing ability, with the age distribution of selection system one would yield 4.5, 6.4, and 2.6 percent more milk than if they had the age distribution of systems two through four, respectively. For a herd maintaining a constant size and having the involuntary losses given in Table 14, the number of young cows that must be kept in all

Table 30. Average percent of the two-year-old level for selection scheme, herd size, and production level

Herd size	Production level	Cow selection scheme 1	2	3	4
40	Low	1.17	1.12	1.10	1.14
40	Medium	1.17	1.11	1.10	1.13
40	High	1.17	1.11	1.10	1.13
120	Low	1.17	1.12	1.11	1.14
120	Medium	1.17	1.12	1.10	1.14
120	High	1.17	1.12	1.10	1.14

systems prevents these differences from being any larger. Rendel and Robertson (1950) attempted to evaluate the effect of longevity on the amount of milk produced by the herd. The results of part of their study are presented in Table 31 along with the similar quantities based on the parameters used in this study.

Table 31. Effect of age on yield

Lactation	Rendel and Robertson		This study	
	Relative value	Cumulative value	Relative value	Cumulative value
1	85.1	85.1	78.1	78.1
2	92.9	89.0	87.0	82.5
3	97.7	91.9	94.3	86.5
4	100.0	93.9	98.0	89.4
5	100.0	95.2	100.0	91.5
6	99.2	95.9	100.0	92.9
7	97.1	96.0	99.0	93.8
8	94.5	96.0	98.0	94.4
9	92.1	95.5	96.2	94.5
10	90.3	95.0	94.3	94.5

The large differences between the corresponding figures from the two studies reflect the difference of the age correction factors used, or the percent of mature yield at each age. Rendel and Robertson (1950) used the age production relationship calculated from Ayrshire data by the paired lactation method. These relationships represented cows that matured early and declined in production significantly over the last five years of their lives. Use of a slower maturing age relationship would increase the importance of longevity as compared with the results of Rendel and Robertson. They also calculated the effect of wastage rate on life expectation and on the relative mean herd yield. Increasing the wastage rate after second lactation using Rendel and Robertson's data reduced the life expectation from 5.31 lactations to 2.99 lactations, but only reduced the actual mean yield two percent. Using the age-production relationships from the present study, the corresponding reduction in life expectation would amount to a reduction of six percent in mean yield. This tends to stress the importance of the age-production relationship when evaluating the effect of longevity. The graph that Rendel and Robertson presented to describe the effect of culling percent, and wastage rate after the second lactation on life expectancy, and relative yield of the herd seemed to be at least partially invalidated by neglecting the different number of heifer calves which would be produced as culling and wastage rates change.

Genetic and Phenotypic Levels of Milk Production

Three measures of milk production were calculated for each herd. The average genetic level (HE basis) of all cows that produced a calf in the period were included in the genetic average for that herd period. These levels are given in Tables 33-38. Two measures of phenotypic performance were also calculated. The total actual production for the period was divided by the herd size times 12/13 to obtain a figure equivalent to the DHI rolling average. These levels are given in Tables 39-44. The second phenotypic measure of production is the average 305 day ME production for each herd period. These levels are given in Tables 45-50. Tables 33-50 are found in the Appendix.

Genetic levels

The genetic levels for each selection system, herd size, and production level for the 20 periods and the average change per period for each factor are given in Tables 33-38.

The genetic levels in period one within a production level vary considerably for the different combinations of the sire and cow selection systems. Because of the method used to generate the genetic levels for each cow selection system, both the genetic levels of the studs and the cow herds had to be specified for a number of periods previous to period one. Sire schemes one and two represent the high and breed-average sire from the same stud. They both progress at the same rate, but are always 1000 pounds HE apart. It was assumed that this stud had been functioning in the same way previous to period one as it did during the 20 periods, that is, similar rate of genetic improvement and distance between the two schemes. Sire scheme three was exactly like scheme two through period one, but then progressed twice as fast as the genetic levels of the bulls in scheme one and two. The genetic levels of all of the cow systems prior to period one were the same and progressed at 78 HE pounds per period through period one.

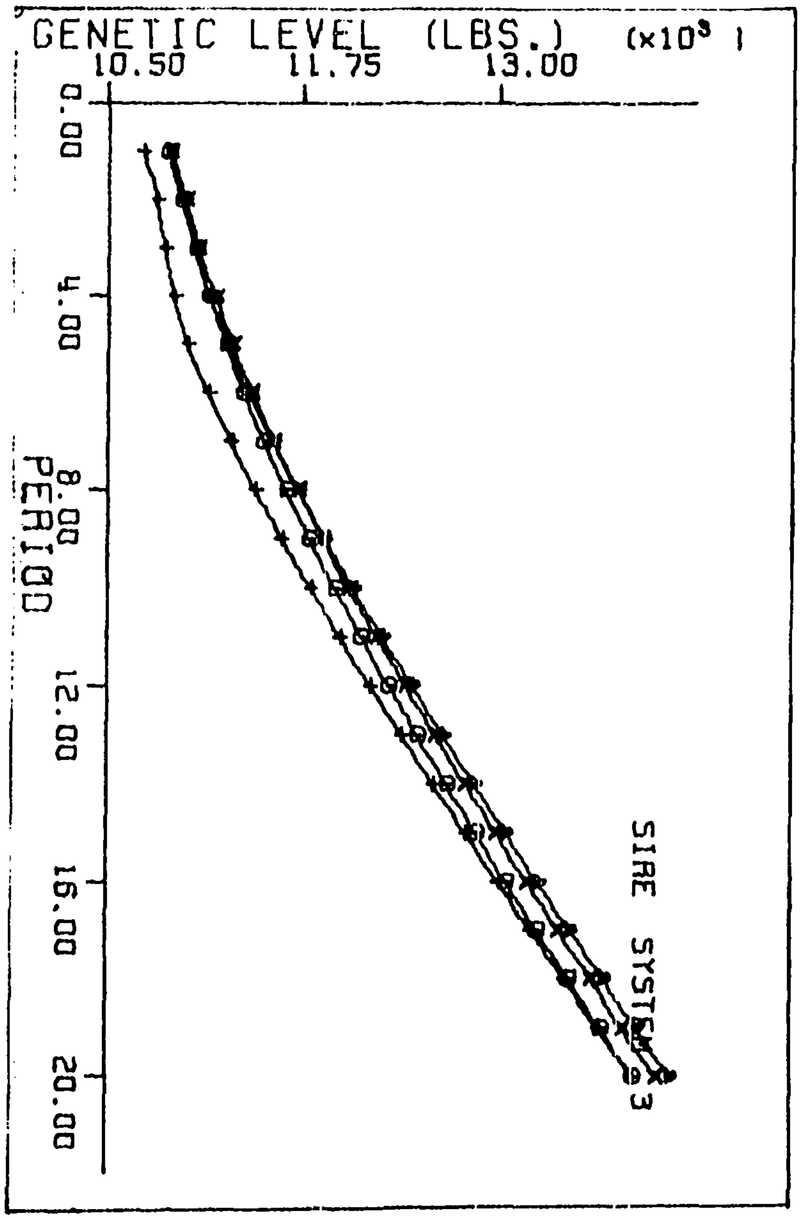
Thus, the genetic levels of the 12 combinations of the selection systems are mainly due to the differences in the sire systems and to a lesser extent to the age distribution and the selection practiced in each cow selection scheme.

Differences between the two herd sizes within production level and selection systems were due to the difference in the selection intensities made possible by the slightly different rearing successes. These differences are very small. Differences among production levels within selection system in period one are approximately one-half the genetic differences between the herds of different production levels given in Table 21.

The genetic level for each period, and for cow and sire selection systems for the 40-cow herd and the medium-production level are plotted in Figure 2. The trends within the other herd sizes and production levels appear to be roughly equivalent to those plotted.

Within sire system one, cow selection system three (youngest herd possible) starts approximately 175 pounds (HE) below the other three systems and progressively loses ground, being over 300 pounds below systems two and four (culling on EBV regardless of age and two-year-olds only, respectively) in period 20. Cow selection system one (calf selection) tends to be about 50 to 75 pounds lower than systems two and four after the initial five periods, with the greatest difference being during the middle periods. Systems two and four are above the other two systems in all periods and differ by only a few pounds during the 20 periods.

Within sire system two, the situation is much as the same, except that the heifer culling system does not drop as far behind cow selection systems two and four and the rate of increase for all cow selection systems is


GENETIC LEVEL (LBS.) (x10³)
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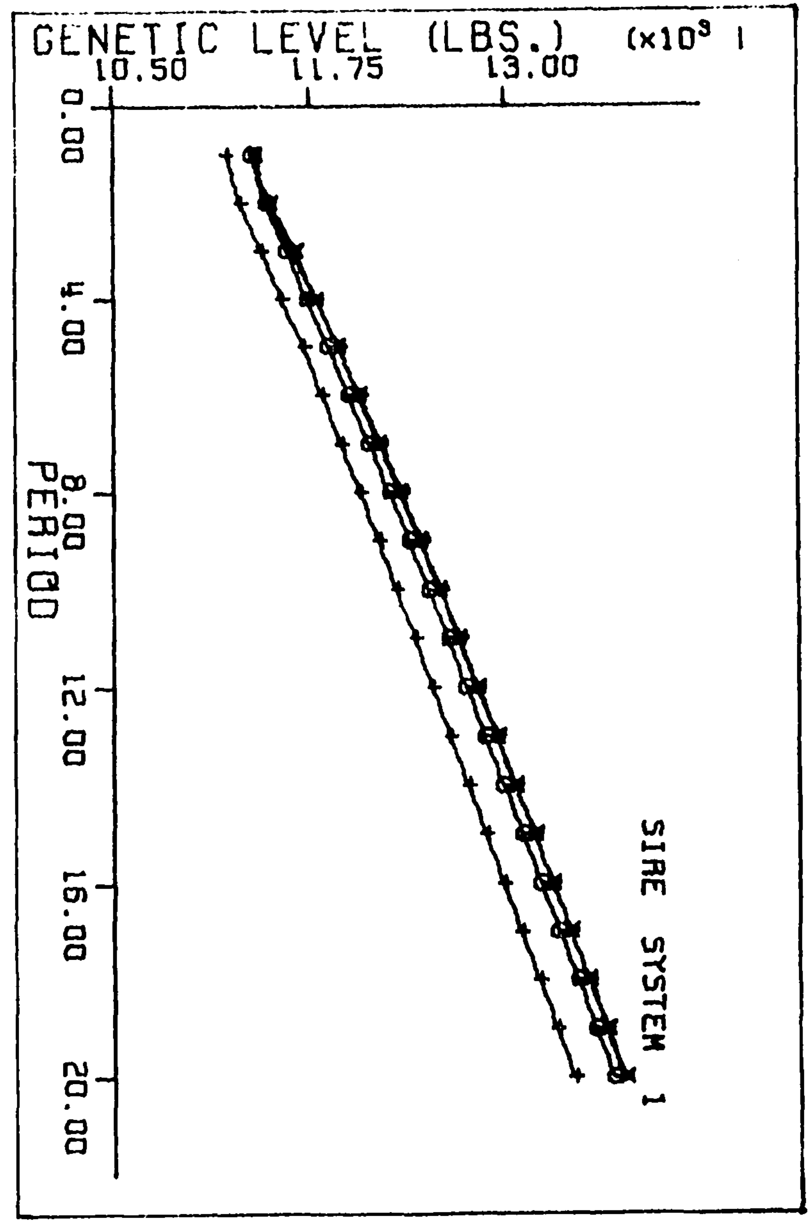
13.00
PERIOD
0.00
4.00
8.00
12.00
16.00
20.00
SIRE SYSTEM 3


GENETIC LEVEL (LBS.) (x10³)
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PERIOD
0.00
4.00
8.00
12.00
16.00
20.00
SIRE SYSTEM 1

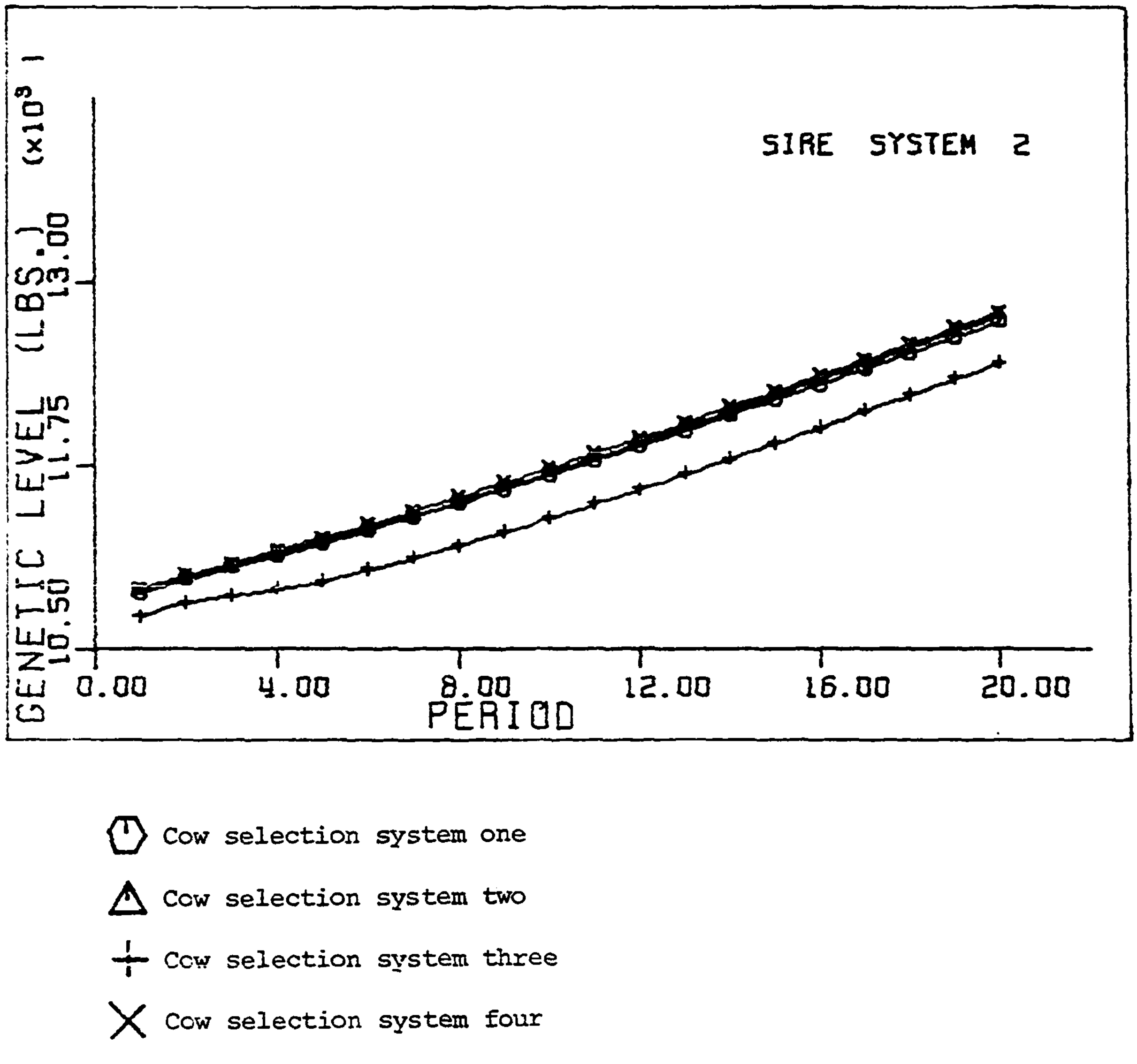


Figure 2. Genetic levels of the combinations of cow and sire selection systems over the 20 periods: 40-cow herd, medium-production level

considerably slower than with sire system one. Since the sires in system one and two are progressing at the same rate, the difference in the rate on change of the herds under the two systems is the advantage of using bulls genetically further above the level of the herd.

Within sire system three, the situation is slightly more complicated. In period one, the cow systems one through four rank third, second, fourth, and first, respectively. Systems one, two, and four are closely bunched. By period nine, system two and four have changed positions and system one is losing its advantage over system three. System two is nearly 100 pounds above system four and system four is approximately 150 pounds above systems one and three in period 20. As was expected, cow selection system three does better with the fast rate of gain in the sires than it did with sire systems one and two.

The effect of the relative position of the genetic level of the sires and the cows can also be seen in comparing the rates of genetic change within a cow and sire selection scheme at the different levels of production (Tables 33-38). The change per period at the lower level of production is at least 10 pounds greater than at the high level of production.

Even with the fast-rate-of-gain sires, cow system three leaves much to be desired as a system to produce maximum genetic gain. For sire system two, cow selection system one is relatively better at producing genetic gain than it is in system three. In sire system one, the relative rate of genetic gain for cow system one is intermediate to its relative position with sire systems two and three. With the fast-rate-of-gain sires, cow system two progresses fastest, systems three and four move slightly slower and system one changes genetically at the slowest rate. Although cow system three was chosen to minimize generation interval, system two, with its voluntary selection, has only five and one-half month longer generation interval (Table 29). When the sires are considerably above the level of the cow herd, the longer length of herd life in system one would tend to suppress genetic gain more than it would with a lower level of sires. This longer generation interval and the low accuracy of selection combine to form the major reasons for the relative ranking of system one. This cow system also demonstrates that generation interval becomes most critical when the rate of genetic gain is the fastest.

Cow selection systems two and four compare favorably to the other two systems for all three sire systems. While neither system is ever very far ahead of the other, their relative position is dependent upon the sire system involved.

The differences mentioned above should be kept in perspective. At no point during the 20 periods are any of the four cow selection systems, within a sire system, much more than 350 HE pounds apart genetically in any of the herds. The differences between the sire systems, within cow selection systems, however, are sometimes more than 1500 pounds HE apart. As was mentioned previously, interactions between several of the cow and sire systems exist. However, these interactions appear to be relatively unimportant in determining the systems which will give the fastest genetic gain.

<u>Rolling DHI average</u>

The DHI levels in actual pounds of milk produced and the average change per period are given in Tables 39-44. Unlike the genetic levels, the rolling DHI averages are strongly affected by the production levels, and the differentiation between the cow selection systems is quite pronounced. The differences between production levels reflect the opportunity the cow has to express her genetic level. This was included in the generation of the phenotypic levels by multiplying the genetic levels by .90, 1.00, and 1.10 for the low, medium, and high production levels, respectively. Several factors contribute to the separation of the production levels of the four cow schemes: (1) the actual differences in the genetic levels of the systems, (2) the differences in the average age distribution of the systems, and hence, the percent of the two-year-old level yielded in actual production, (3) the differences in the build up of permanent environmental effects, and (4) the differences in the percent-days-in-milk between the systems. The actual differences between the systems with regard to item (1) have just been discussed.

As was shown earlier, there are fairly large differences in the average percent of the two-year-old level between the four systems. Thus, the actual yield from animals with the age distribution of system one would produce 4.5, 6.4, and 2.6 percent more actual milk than their phenotypically equivalent counterparts with the age distribution of systems two through four, respectively. Even at the 12,000 pound level of production this would amount to approximately 540, 770, and 330 pounds of difference in the actual production, respectively.

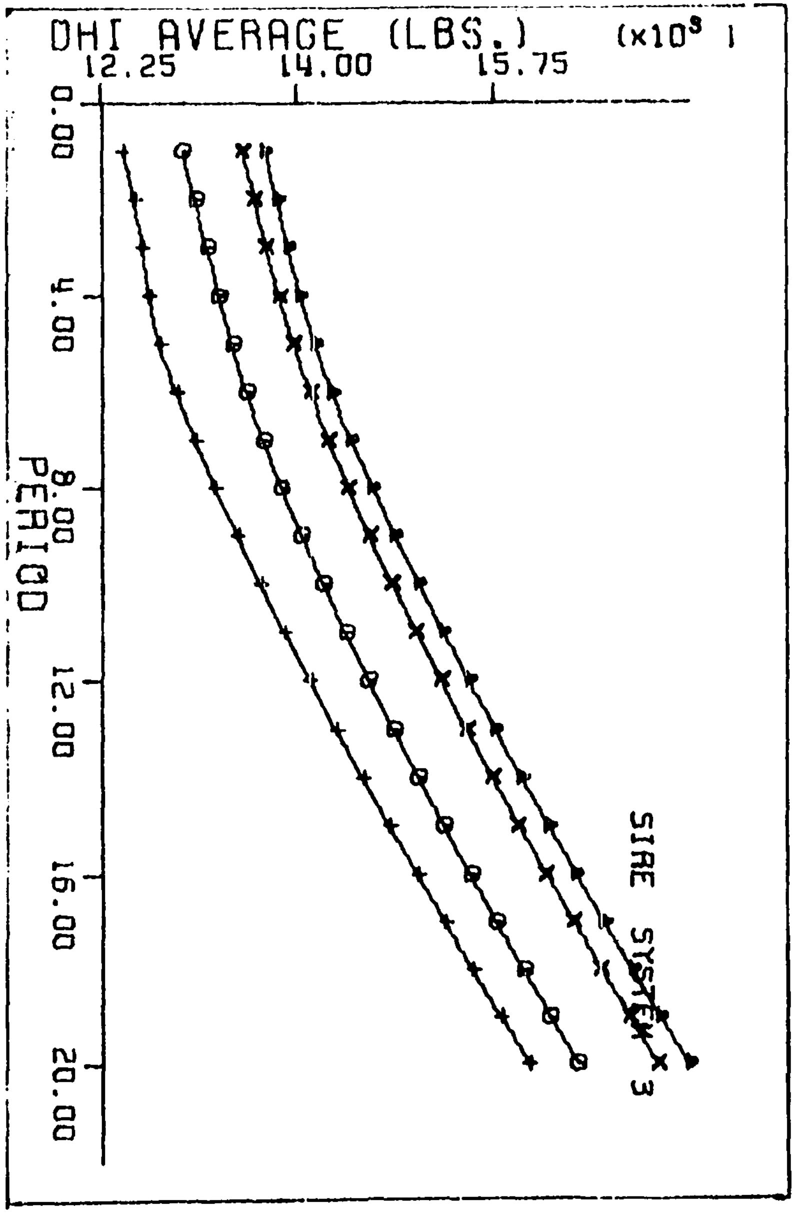
Systems two and four both tend to choose animals with better than average permanent environmental effects. This effect is considerably stronger in system two because the continued selections tend to reinforce the build up of positive "permanent" environmental effects. System four, however, loses some of the advantage of the positive effects in the lactations after the selection (Tables 4-9). Neither system one nor three selects animals with better than average permanent environmental effects since no selection involving the cow's own record is practiced.

The fourth effect which will influence the relative positions of the systems is the percent-days-in-milk. System one is approximately 1.6 percent below the other three systems. This difference would offset part of the advantage that system one obtains from the older age distribution. These three forces combined with the genetic differences are the main causes of the differences between the actual production from the four cow selection systems.

The differences in the levels of the four cow selection systems within sire systems in period one can be used to quantitate the effects just discussed. By comparing systems one, two, and four, which are nearly the same genetically in period one, the total effect of the four causes can be seen. Selection system two ranks the highest, being 200 pounds of actual production above system four. This advantage is mainly due to the large positive influence of the permanent environmental effects, as the percent-days-in-milk are about equivalent for the two systems and system four has an age distribution more favorable for actual milk production and a slightly higher genetic level than does system two. System four has over a 500 pound advantage over system one. Again this appears to be due primarily to the advantage in permanent environmental effects, and to a lesser extent to a higher percent-days-in-milk and the slight advantage in the genetic level. This 500 pound advantage is over and above the advantage that system four yields to system one in the age distribution of the herd. System one is nearly 550 pounds above system three. This difference is mainly due to the genetic advantage of system one and the substantial advantage of system one in the age distribution of the herd for high levels of actual milk production.

The actual production levels for all of the selection systems over the 20 periods for the 40-cow herd at the medium-production level are given graphically in Figure 3. The differences between the selection systems can easily be seen. For sire systems one and two, the change over time for each cow selection system is fairly linear. While the slopes of the lines for systems two and four are almost identical, the slope for system one is slightly less inclined and the slope for system three has markedly less pitch. Within sire system three the picture is quite different. The curvilinearity of these lines is due to the slower rate of genetic change prior to period one for this sire system explained at the beginning of the section on genetic levels. While in any period the cow selection systems rank the same as they did in the other two sire systems, the slopes for the different cow selection systems under sire system three are considerably less parallel. The calf culling system is definitely losing its advantage over the herd with the youngest age distribution. This is due almost entirely to the decrease in genetic superiority of system one. The majority of the difference in the two systems in period 20 is due to the older age distribution in selection system one.

While there is a change in the magnitude of the differences between the cow and sire selection systems that have been discussed relative to the medium level of production, the relative trends that have been discussed are applicable to all three levels of production.


DHI AVERAGE (LBS.) (x10³)
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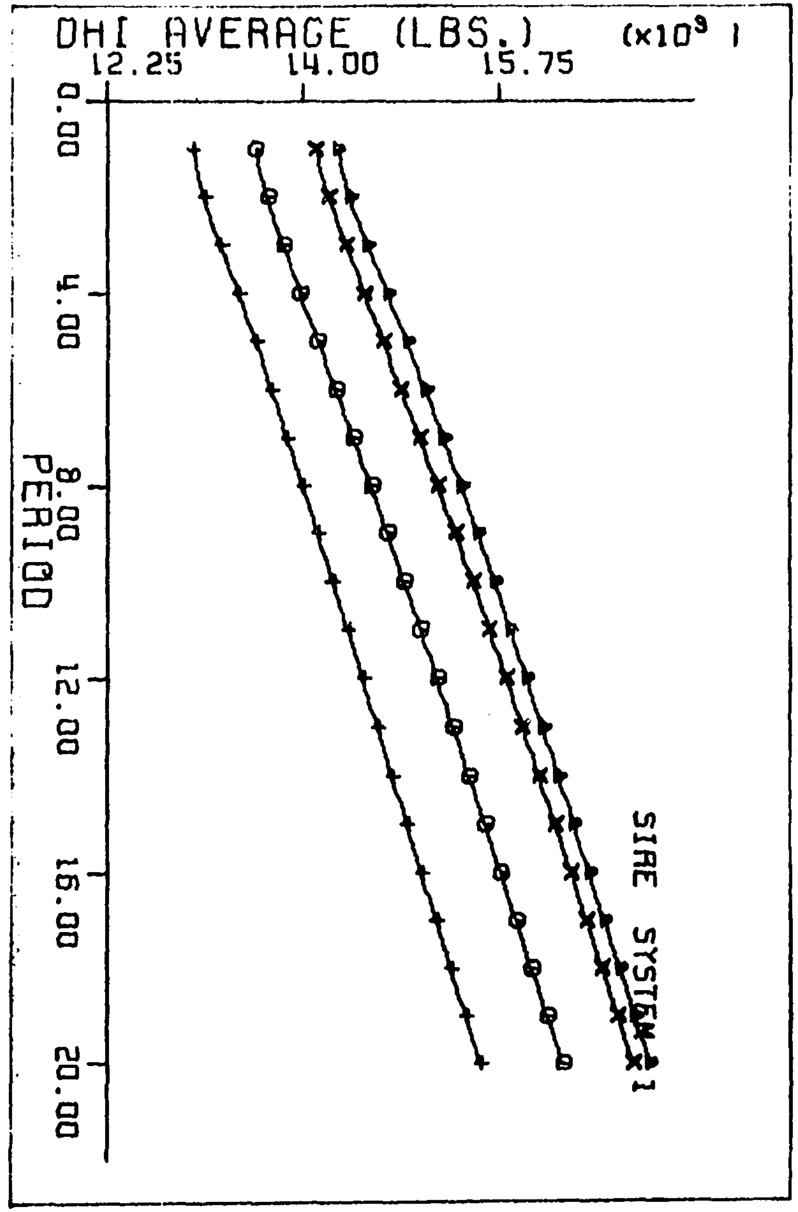
14.00
15.75
PERIOD
0.00
4.00
8.00
12.00
16.00
20.00
SIRE SYSTEM 3


DHI AVERAGE (LBS.) (x10³)
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14.00
15.75
PERIOD
0.00
4.00
8.00
12.00
16.00
20.00
SIRE SYSTEM 1

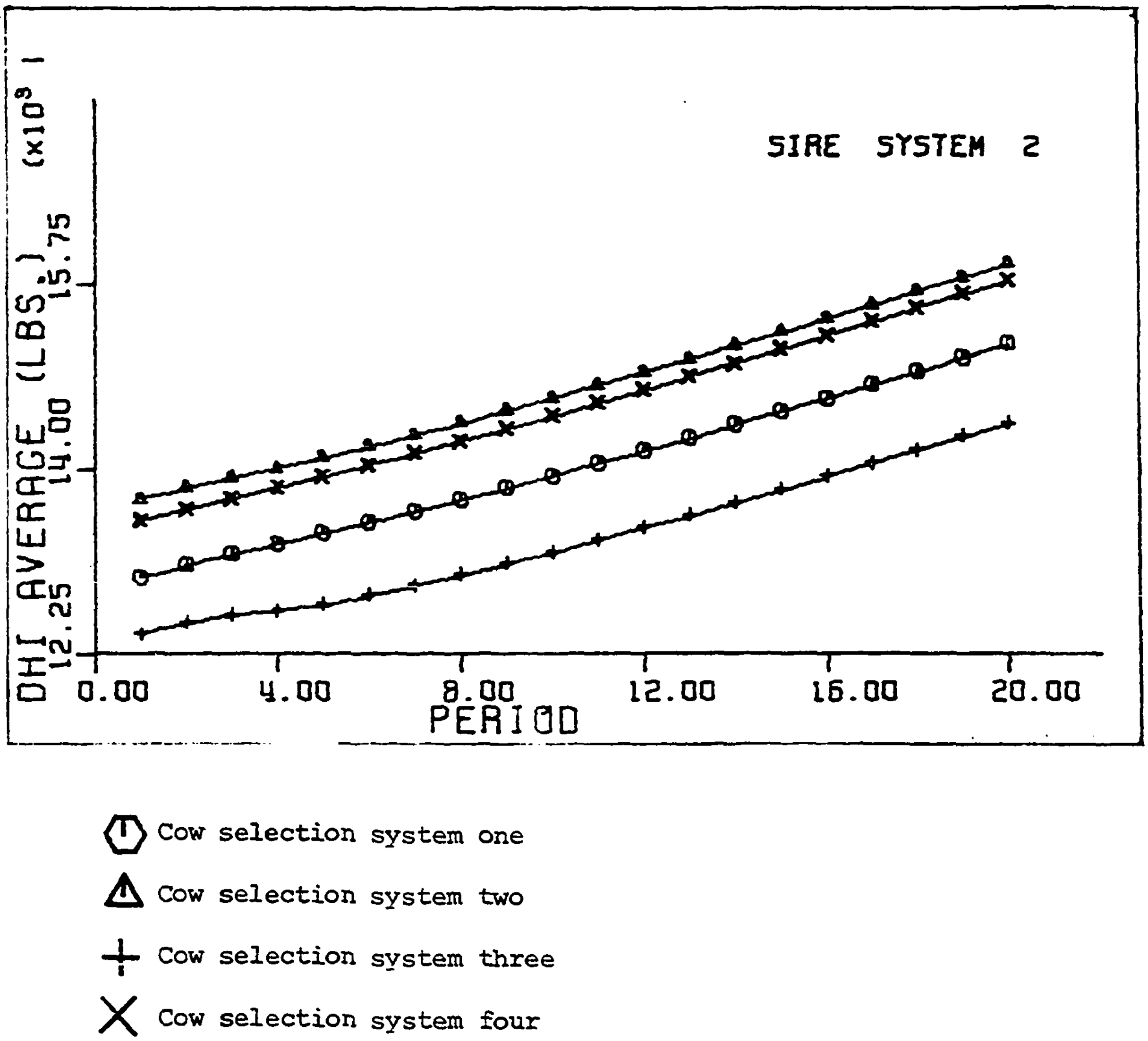


Figure 3. DHI levels of milk production for the combinations of cow and sire selection systems over the 20 periods: 40-cow herd, medium-production level

The change per period, the regression coefficient of DHI level on period number, in the DHI level from period one to 20 for each selection system, herd size, and production level are given in the last rows of Tables 39-44. Unlike the rates of genetic change, the rate of change in the actual production increases as production level increases. However, differences in the rate of change between production levels and herd sizes within selection systems are quite small compared with the difference between selection systems. For the 40-cow herd, medium-production level, the rates of change for the 12 combinations of the selection system with their rank within sire systems in parentheses are:

		Cow system			
		1	2	3	4
Sire system	1	147(3)	149(2)	136(4)	152(1)
	2	116(3)	118(2)	106(4)	120(1)
	3	188(4)	204(1)	197(3)	199(2)

Cow selection systems one through four rank third, second, fourth, and first, respectively within sire systems one and two, but under sire system three, the cow systems rank fourth, first, third, and second.

<u>305 day ME production</u>

The 305 day ME production levels for each selection system, herd size, and production level and the rates of change over time are given in Tables 45-50. Since they have little or no effect on the economic situation for the herds other than their relation to actual production, discussion of them will be very limited. The main point of including these levels in the manuscript is to give individuals accustomed to viewing ME averages a reference point from which to evaluate the production levels of the herds. These ME levels are free of the effect of the age distribution, and of the percent-days-in-milk. However, each lactation started in the herd, whether completed or not, is given equal weight. Thus, for the selection systems where producing cows are selectively culled after five months of production these lower producing cows are given full weight and would tend to lower the average compared with the relative DHI levels.

Summary of genetic and phenotypic levels

The genotypic and phenotypic averages for the 20 periods for each herd size and production level are given in Table 51. The genetic differences between the levels for the two herd sizes within production level and selection scheme combinations are extremely small and are due to the differences in rearing success for the two herd sizes. The differences between the genetic means for the different production levels within the other factors have been reduced from approximately 130 pounds (HE) in period one to approximately 65 pounds (HE) for the average over the 20 periods. This reduction in the differences is caused by herds at each production level all using the same bulls. These differences between production level vary slightly between cow selection systems, but, are more constant for sire systems within a cow system.

The differences between the DHI levels for the two herd sizes within the other factors is approximately 150 actual pounds and is due to differences in the rearing success and to slight differences between the age distributions. In contrast, the differences between the production levels are in the neighborhood of 2300 pounds. This difference represents the difference in the opportunity of the cows in the different production levels to express their genetic ability and the genetic differences between the production levels. As was explained earlier, the opportunity to express genetic levels was built into the results. Cow selection systems one through four rank third, first, fourth, and second, respectively. The difference between the systems increase as the production level increases. The correspondence between the genetic and phenotypic measure for each system within the other factors is quite close but the factors described earlier in the section tend to change the relative differences between the systems.

The 305 day ME levels for the systems are closely related to the actual production levels. However, as is usually found, the ME levels tend to be higher than the actual averages. The amount that the ME average is higher than the actual average varies with the average age of the herd. The largest increase occurs with cow selection system three.

Description of the Factors Influencing Profit

Table 32 was prepared to show the various income and expense items that change between different levels of the selection systems, herd sizes, production levels, rearing costs, milk price, and feed price each within the levels of the other factors. This table can be used as a guide in following the discussion of the results. Those items with an "S" vary only slightly from level to level and can be disregarded without any significant loss in explaining changes in profit. Those items with an "F" are fixed and do not contribute to change for that factor. The items denoted by a "V" are major sources in variation and need to be considered in evaluating

Table 32. Effect of levels of the physical and economic factors on the variability of income and expense items

Items	Factors							
	Cow scheme	Sire scheme	Herd size	Prod. level	Periods	Rearing costs	Feed price	Milk price
Income								
1. Milk								
Pounds	V	V	V	V	V			
Price						F	F	V
2. Heifer calves								
Number	V	F	V	S	F			
Price (fixed)								
3. Bull calves								
Number	V	F	V	S	F			
Price (fixed)								
4. Cull cows								
Pounds	V	F	V	S	F			
Price (fixed)								
5. Cows sold dairy								
Number	V	F	V	S	F			
Price				V		F	F	F
Expense								
1. Non-variable costs	F	F	V	F	F	F	F	F
2. Interest on cows								
Valuation	F	F	F	V	F	V	F	F
Rate (fixed)								
3. AI costs								
1st services	V	F	V	S	F			
Price		V				F	F	F
4a. Feed-GMP								
Amount	S	F	V	S	F			
Price						F	V	F
4b. Feed-Prod.								
Pounds	V	V	V	V	V			
Price						F	V	F
5. Rearing cost								
Number	V	F	V	S	F			
Price						V	F	F
6. Additional cost for high milk prod.	V	V	S	V	V	F	F	F

changes in profit. Even within this last group, there is considerable variation in the magnitude of the effect. When considered on a per cow basis, all of the items for the factor herd size denoted by a "V", with the exception of non-variable costs, would be changed to an "S". For income items two, three, and four the price per unit is fixed. Interest rate is the only fixed expense item, however, the cost factors for expense items one, three, and six and income item five do not vary independently of the physical factors.

The income and expense items given in Table 32 can be divided into two groups, those which change with the pounds of milk produced and those which do not. Only milk income, feed costs for production, and the additional cost of high milk production vary with the level of milk production. The remainder of the items are constant over time. The profit equation can be rewritten as:

Profit = (a) (milk price - feed cost for production - the additional cost of high milk production) x (the pounds of milk produced)

+ (b) non-milk income - the total feed cost for maintenance, growth, and reproduction - (the number of heifers reared) x (the rearing cost) - the non-variable costs - the interest on cows - cost of artificial insemination.

The quantity within the parentheses in term one will be referred to as the marginal milk price. In this form of the profit equation, it can be seen that the profit for a particular system is dependent upon enough net income from part (a) of this equation to offset the negative balance of the items in part (b) of the equation. From period to period within the same herd, all of the income and expense items except those in term one of the equation are constant. Thus, the increase in profit with time would be proportional to the increase in the actual pounds of milk produced except for the slight increase in the feed requirements as production increases and except for the change to a higher level of additional cost for high milk production. To obtain similar profit from two selection systems which differ in the dollar value of part (b) of the profit equation, the difference must be compensated for by the marginal income from additional milk production. The unit prices for the expense and income items were given in Table 3. A description of the factors which do not vary with milk production and their approximate variation on a per cow basis follows:

Income from cull calves and cows, and cows sold for dairy--$90, $130, $155, and $130, for cow schemes one through four, respectively. The income from system three is $10 per cow higher for the medium production level and $30 higher for the high production level. This income provided a sizeable second source of income from the dairy herd. Cow selection system one has the smallest number of calves born, the fewest raised, and consequently the fewest cows sold for beef. Systems two and four sell less calves than system one, but sell considerably more cows for beef. System three is very similar to systems two and four except that some of the cows removed from the herd are sold for dairy purposes at $50 to $125 above beef price, thus, yielding a higher non-milk income for system three.

Cost of feed for growth, maintenance, and reproduction--$108, $149, and $190 per cow for the low, medium, and high levels of feed price. The feed costs attributable to growth, maintenance, and pregnancy vary little except for the different levels of feed prices. The total requirement in

Mcal of NE per herd period for each cow culling system vary less than 1,000 Mcal in the 40-cow herd. When this is divided by the herd size, this is a negligible difference.

Rearing cost--$60, $78, and $95 per cow for the low, medium, and high rearing cost for selection system one; $118, $155, and $190 per cow for the low, medium, and high rearing cost for selection systems two, three, and four. Rearing cost varies with the number of heifers raised and with the rearing cost per heifer raised. System one raises only about half as many heifers per period as do the other three systems. Thus, the rearing cost for the system where calves are culled is considerably lower than the rearing per cow for the other three systems.

Non-variable costs--$340 and $245 per cow for the 40 and 120 cow herd. Non-variable costs are $95 higher for the 40-cow herd than they are for the 120-cow herd. This results mainly from the higher labor and higher fixed costs per animal associated with the smaller herd size.

Interest on cows--ranged from $25 to $36 per cow, increasing from the lower limit as rearing cost and production level increase. Interest per cow was calculated as the value of the cow times 13/12 times the yearly interest rate. Because cow valuation increased as rearing cost and production level increase, the interest per cow increased correspondingly. The valuation for cows in the low production level and with low rearing cost was $325, while the valuation at the high levels of these factors was $475.

Cost of AI--$9.50, $12.50, and $18.50 per cow period for breed-average, high, and fast-rate-of-gain sires for cow system one. Cow systems two, three, and four would be $1.00 to $2.50 higher for the three types of sires. The AI cost per cow varies with the number of calves born and with the sire system used. Cow system one has approximately 10 percent less breedings than the other systems. The price per insemination varies with the sire selection system.

Feed costs to produce one-hundred pounds of milk, not including feed for maintenance, growth, and pregnancy, were approximately $0.84, $1.16, and $1.47 for the three feed prices. These quantities vary slightly with the level of production. The additional cost for high milk production was $0.05, $0.10, $0.15, and $0.20 per cwt of milk for cows producing between 13,000 and 15,000, between 15,000 and 17,000, between 17,000 and 19,000, and in excess of 19,000 pounds, respectively. This would amount to $7, $16, $27, and $40 per cow at the medium level of each production range, respectively. At the high levels of production this is an important cost. When considering the cost per hundred pounds of milk, the increase due to the additional cost of high production is offset by spreading the costs that do not vary with milk production over more pounds of milk.

Several Measures of Profit

Four measures of profit were chosen to describe the different systems. The profit results will be presented in terms of periods. A period is equal to 13 months. When the operator's labor income, $5200, and the interest for his equity are added to the profit per year, the result is an indication of the amount available for living expenses and for increasing equity each year. To make this important measure of profit as understandable and as easy to handle as possible, it was expressed on a per cow-period basis. In this form, however, herd size must not be forgotten. These estimates of profit are summarized in Tables 52-57.

The second measure of profit was the profit per cow in period 20. This measure was calculated to evaluate the systems after they had sufficient time to separate. These estimates are given in Tables 61-66.

The third measure of profit calculated was the present value of the total profit. It was calculated as:

$$\sum_{j=1}^{20} \frac{P_j}{(1+i)^j},$$

where P_j is the profit in period j, and i is the interest rate. The purpose of this measure of profit is to discount future profit to its value in period one. Since there are no differences in the hypothesized investment in any of the culling systems and since there are no drastic changes in the rank of the four culling systems over time, the need for this measure is drastically reduced. This judgement, however, is after the fact. The estimates of present value of the profit are presented in Tables 70-75.

The final measure of profit was the change in profit over time. This measure was expressed in two ways. First, the change per period was calculated as the regression of profit on time (Tables 79-84). Second, the trend over time was examined by plotting the profit of individual periods for each selection system at the medium level of the three economic factors (Tables 85-90). The two measures for each selection system differ only by any effects which are constant over all periods.

Average profit per period

The average profit per cow per period is given in Tables 52-57. These tables are arranged much like the tables summarizing each measure of milk production. The cow and sire systems are arranged across the top of the table. The price levels of the three economic factors are arranged sequentially along the right hand side of the table. For all of the price factors the numbers 1, 2, and 3 correspond to low, medium, and high levels given in the outline, Figure 1. Within a column, sire and cow system, the figure represents the profit from the physical inputs and outputs of that system evaluated at the different levels of the economic factors. That is, the only change in the column is the change in the price of feed and milk, and rearing costs. The differences between the tables for the herd sizes within the same production level are attributable to the difference in the non-variable costs per cow and to the small differences in milk production caused by the rearing success. Differences between the tables due to production levels within the same herd size are due to the differences in the actual pounds of milk produced by the herds. These differences between the tables will be discussed at the end of this section. Trends within the six tables are fairly consistent. For this reason, one herd size and production level, the 40-cow herd at the medium level of production, was chosen to be discussed in detail.

The average profit per cow per period for the 40 cow herd at the medium level of production are graphically given in Figures 4-6. These three figures correspond to the profit found in Table 54. The selection systems are arranged on the horizontal axis and the vertical axis is profit. Each curve represents evaluation of a selection system at combination of the feed price and rearing cost specified at the right. Within cow schemes and price levels the three sire schemes rank first, third, and second, respectively. The only economic differences between the sire schemes is the differences in the AI costs and the differences in milk production. Since the

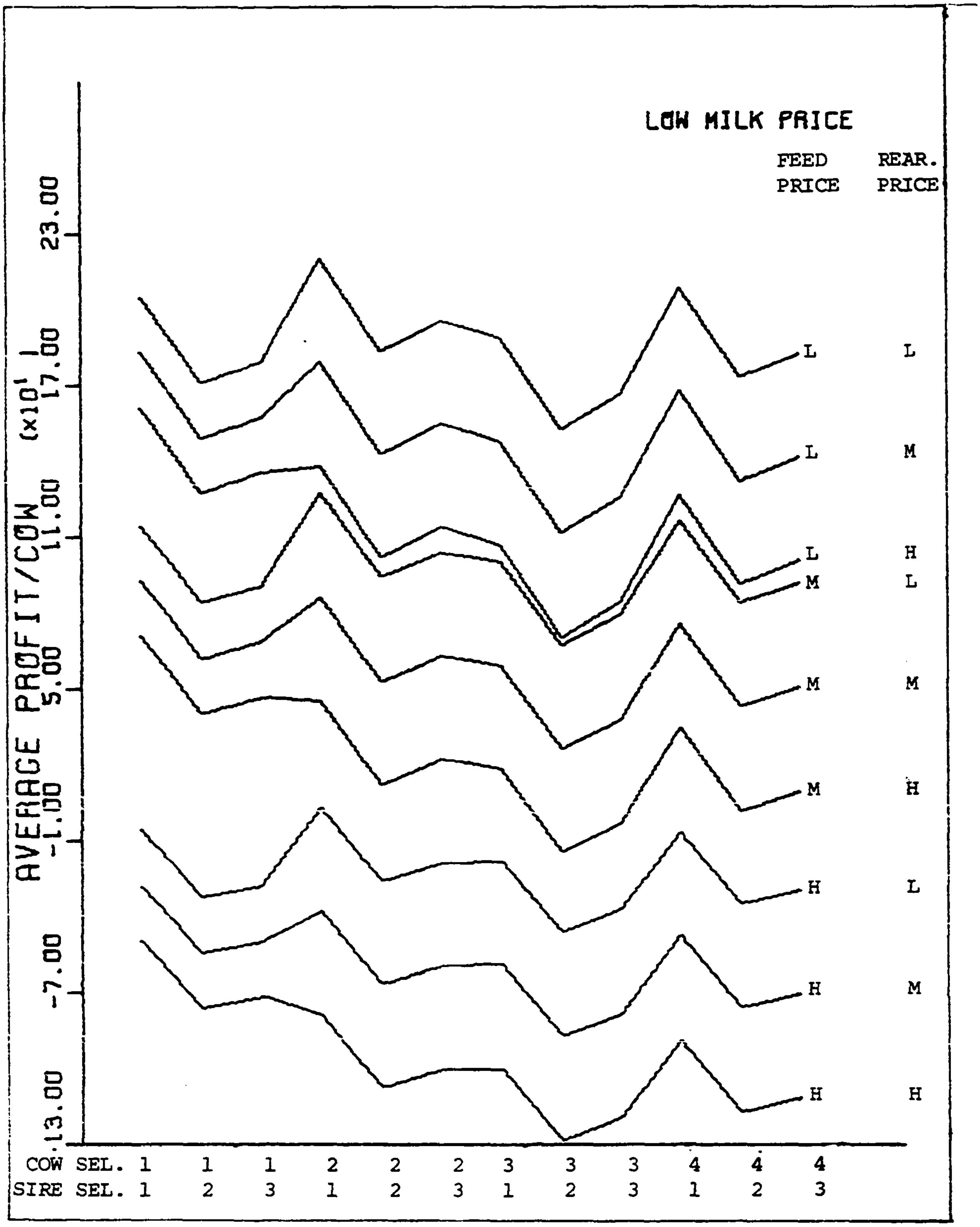


Figure 4. Average profit per cow per period at the low milk price: 40-cow herd, medium-production level

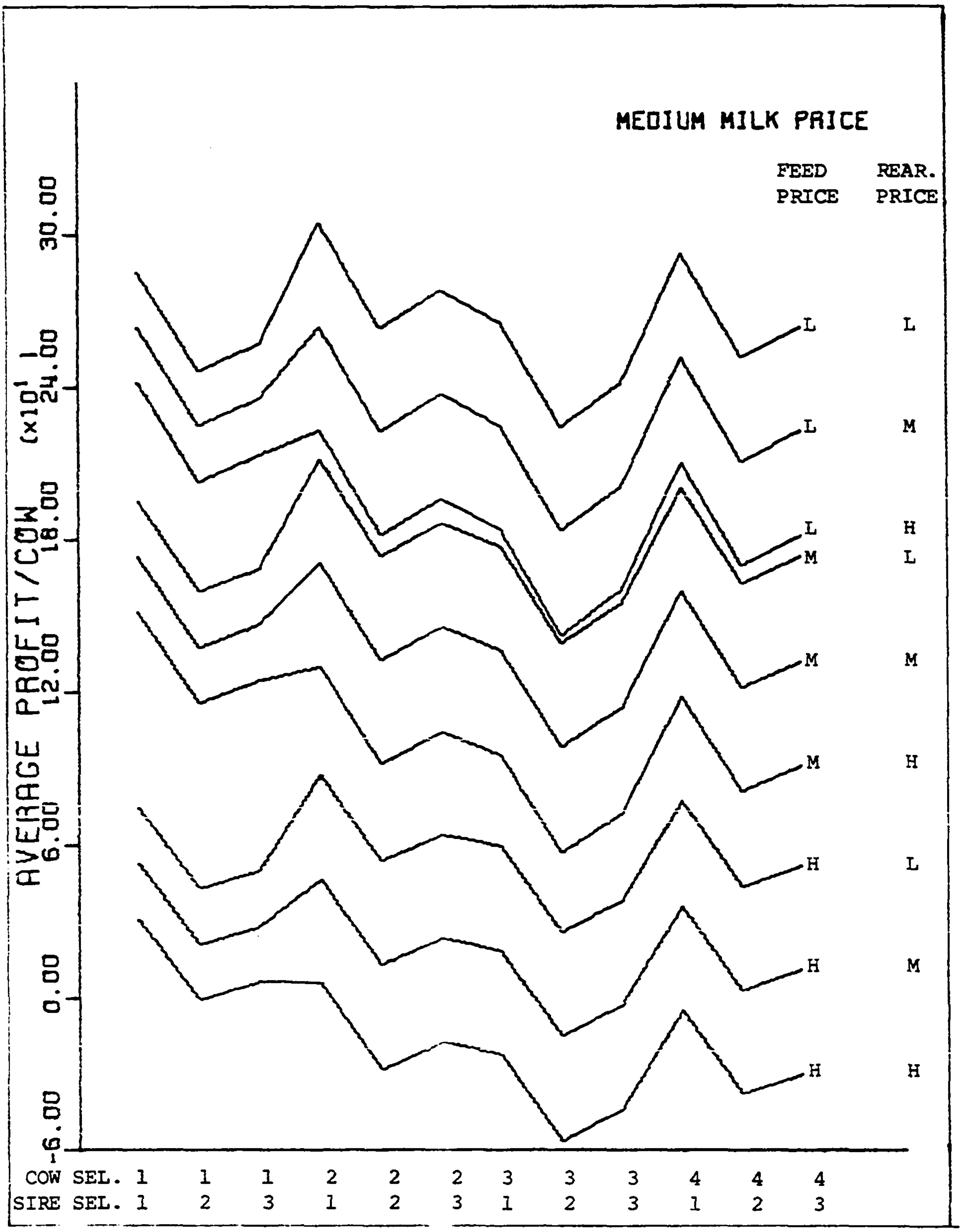


Figure 5. Average profit per cow per period at the medium milk price: 40-cow herd, medium-production level

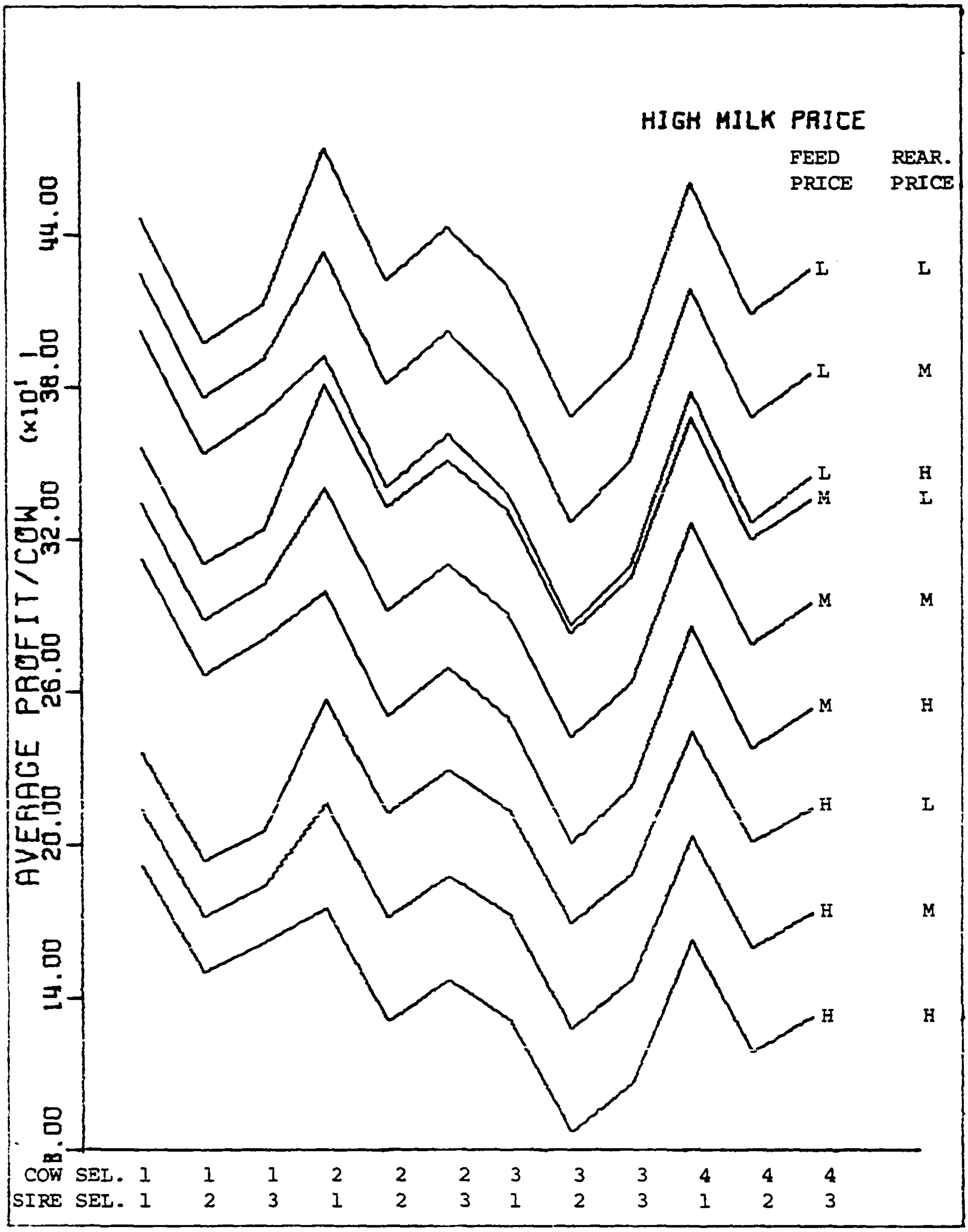


Figure 6. Average profit per cow per period at the high milk price: 40-cow herd, medium-production level

AI costs per cow vary only slightly, the three sire systems rank as they did for milk production.

Within sire systems, cow selection systems two, three, and four rank first, third, and second, respectively. In this ranking, system one has been excluded and will be discussed later. Cow systems two, three, and four raise the same number of heifers. Thus, the rearing costs do not cause any differentiation between the three systems. Only two items have major effect on the ranking of these systems. Cow system three has substantially higher non-milk income. This advantage ranges from $25 in the herd at the low production level to $55 in the herd at the high production level. Systems two and four have nearly identical non-milk incomes. Second, there are substantial difference in the actual production from the three systems. The difference between system two and system three vary with the production level and the sire system and range from 1200 pounds to 1600 pounds (Table 51). Cow system four is intermediate, but is much closer to system two. For the herd size and production level graphed, the differences in actual production between the three systems are:

	Sire systems		
Cow systems	One	Two	Three
Two-three	1427	1432	1387
Two-four	184	169	233
Three-four	-1243	-1263	-1154

As was mentioned earlier, cow system three has a slightly more competitive production under sire system three than it does with the other sire systems. The differences in the profit for the three systems are equal to the difference in non-milk income plus the difference in milk production times the marginal milk price. While the magnitude of the difference varies, system two consistently has a higher profit than system four and both two and four have higher income than system three. When the marginal milk price is the lowest, low milk price and high feed cost, system three will have the least disadvantage. These changes can be seen in the graphs in Figures 4-6. Progressing from the low to high milk price exaggerates the differences in the systems, while increasing the feed costs reduces the variation. Increasing the rearing cost reduces the profit from all three systems by a constant amount. Cow system three fares best at the high production level where it has the higher non-milk income.

Cow selection system one has not been discussed previously because its relative rank changes with the different levels of the economic factors and because it differs from the other three systems in its physical inputs and outputs. The main difference between cow selection system one and the other three systems is in the number of heifers raised for replacements. System one rears only half as many heifers as the other three systems. For the herd size and production level plotted, the differences in the actual milk production between system one and the other three systems are:

	Sire systems		
Cow systems	1	2	3
One-two	-788	-733	-851
One-three	639	705	536
One-four	-604	-568	-618

Milk production for system one is approximately half way between systems four and three. The non-milk income from system one is the lowest of the four cow culling systems. This difference in non-milk income is constant for all price levels and does not affect the relative ranking of the systems as the price levels change.

Cow selection system one is superior to system three at all levels of the economic factors. The two systems are the closest when milk price is low and feed costs are high, low marginal milk price, and when the rearing cost is low. This combination of levels minimizes the disadvantages of cow system three without making fullest advantage of the best point of system one.

When compared with cow selection systems two and four, system one ranks first, second, and last depending upon the levels of the economic factors. At the low rearing cost, system one yields less profit than system two or four. At this rearing cost, system one has a $65 advantage per cow in rearing cost and a $40 disadvantage in non-milk income. The advantages of systems two and four in milk production can offset this advantage at nearly all of the marginal milk prices. The advantage of systems two and four is even greater as the marginal milk price increases, that is, as milk price increases and/or feed price decreases.

At the medium rearing cost, system one has a $75 advantage in rearing cost, with the situation for non-milk, and milk income remaining constant. For this rearing cost, the rank of system one is dependent upon the levels of milk price, and feed price, and also the sire system used. That is, the $35 advantage that system one has with regard to rearing cost and non-milk income is offset by the milk differences at some of the milk and feed prices but not by all of them. As was explained earlier, the milk difference between the cow system one and cow systems two and four is greater moving from sire system two to sire system one to sire system three. Thus, with sire system two, cow system one ranks above system two and four at all but the highest marginal milk price. For each of the other two sire systems, a lower marginal milk price is needed for system one to rank first. However, cow system one ranks first at the medium rearing cost and low milk price regardless of feed price for all sire systems. The medium rearing cost is the break even for cow system one. Although the rank of system one changes with marginal milk price, the sizes of the differences are not great.

At the high rearing cost, system one ranks first at all levels of the economic factors. The $55 advantage of cow system one over system two and four in rearing costs and non-milk income can not be offset at any of the milk and feed prices used with the differences in milk production that exist between the systems.

The mean effects for each of the price levels are summarized in Tables 58-60. The figures in the body of the table are the average profit for each selection system for the level of the factor specified to the left, averaged over all levels of the other price. Both herd sizes for a given production level are given in each table. The average profit over all levels of the three economic factors and profit at the medium level of all of the economic factors is also given for each selection system.

The differences between the tables for the two herd sizes with production level are mainly due to the $95 per cow difference in the non-variable costs. The larger herd size would have slightly less income from milk, but this difference is quite negligible. From Table 32, it can be seen that the differences between production levels within herd size are due to differences in pounds of milk produced, value of cows sold for dairy, interest on cows, feed cost for production, and the additional cost for high milk production. The value for cows sold for dairy, only affects cow selection system three, increasing the non-milk income per cow for this system $10 and $30 from the low level of production to the medium and high levels, respectively. Interest on cows only varies from $25 to $36, thus does not contribute much to difference between levels. The three remaining items provide the major differences between the production levels. These three constitute the marginal milk price. As has been explained earlier, milk price is independent of level of production, feed cost for production is slightly influenced by the level of production, and the additional cost of high production is determined by level of production. Thus, there are two counteracting forces between production levels. The higher milk production of the medium and high production levels increases profit for these levels, while the higher feed and additional cost for high production tend to reduce the marginal milk price, thus reducing profit per pound of increased of production. The net change is a substantial increase in profit from the low level of production, but the increase is not proportionally as large as the increase in milk production.

For the remaining three measures of profit, a format similar to the one used in this section will be used. Much of the detail given in this section will be omitted, however, and differences from the effects on average profit per period per cow will be emphasized.

Profit per cow in period 20

The profit per cow in period 20 for the 12 selection systems is given in Tables 61-66. These tables are arranged in similar manner to the tables of average profit per cow per period. The body of the tables contain the profit per cow when the physical inputs and outputs of the 12 selection systems in period 20 were evaluated at the different levels of the economic factors. After nearly 23 years of selection (20 periods), the difference between the various selection systems has had time to be expressed. This is the main reason for evaluating this measure of profit. This measure of profit will be discussed for the 40-cow herd at the medium level of production.

The profit in period 20 for the 40-cow herd at the medium level of production is presented graphically in Figures 7-9. The ordinate of the three graphs changes at the same rate, but the origin of the axis moves upward with each increase in milk price. The effect of higher milk price is to enlarge the differences between the systems. The selection systems are arranged on the horizontal axis in the order that they appear in the tables of profit.

In period 20, sire selection system three ranks slightly above system one and considerably above system two. The size of the advantage of system three over systems one and two is largest in cow system three, followed by cow system two, four, and one. This order corresponds to the generation interval of the four cow systems. The economic advantage of sire system three is due to the higher level of milk production in period 20. The starting point of sire system three was arbitrarily set at the same level as the breed-average sires, system two. This allowed for the comparison to

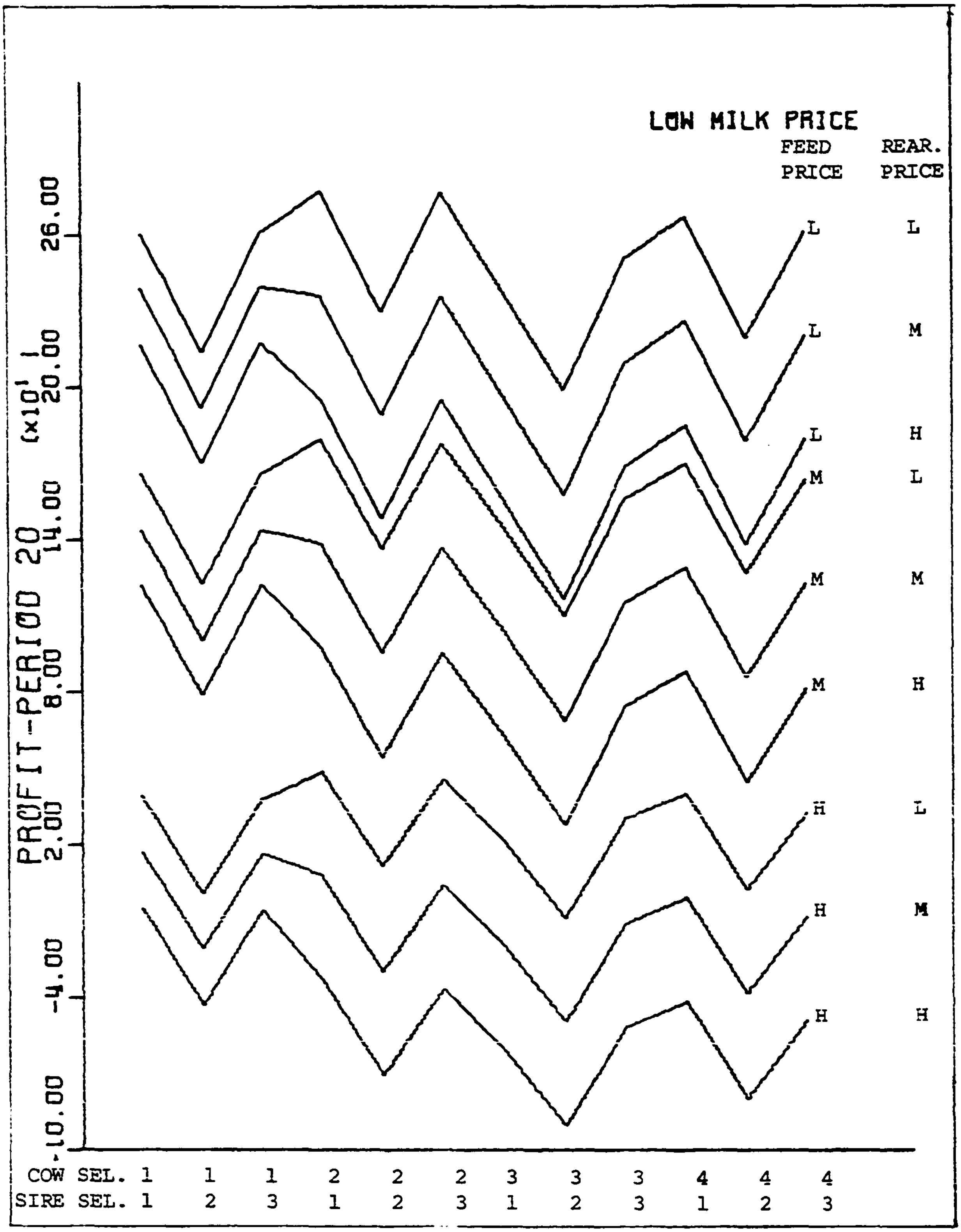


Figure 7. Profit in period 20 per cow at the low milk price: 40-cow herd, medium-production level

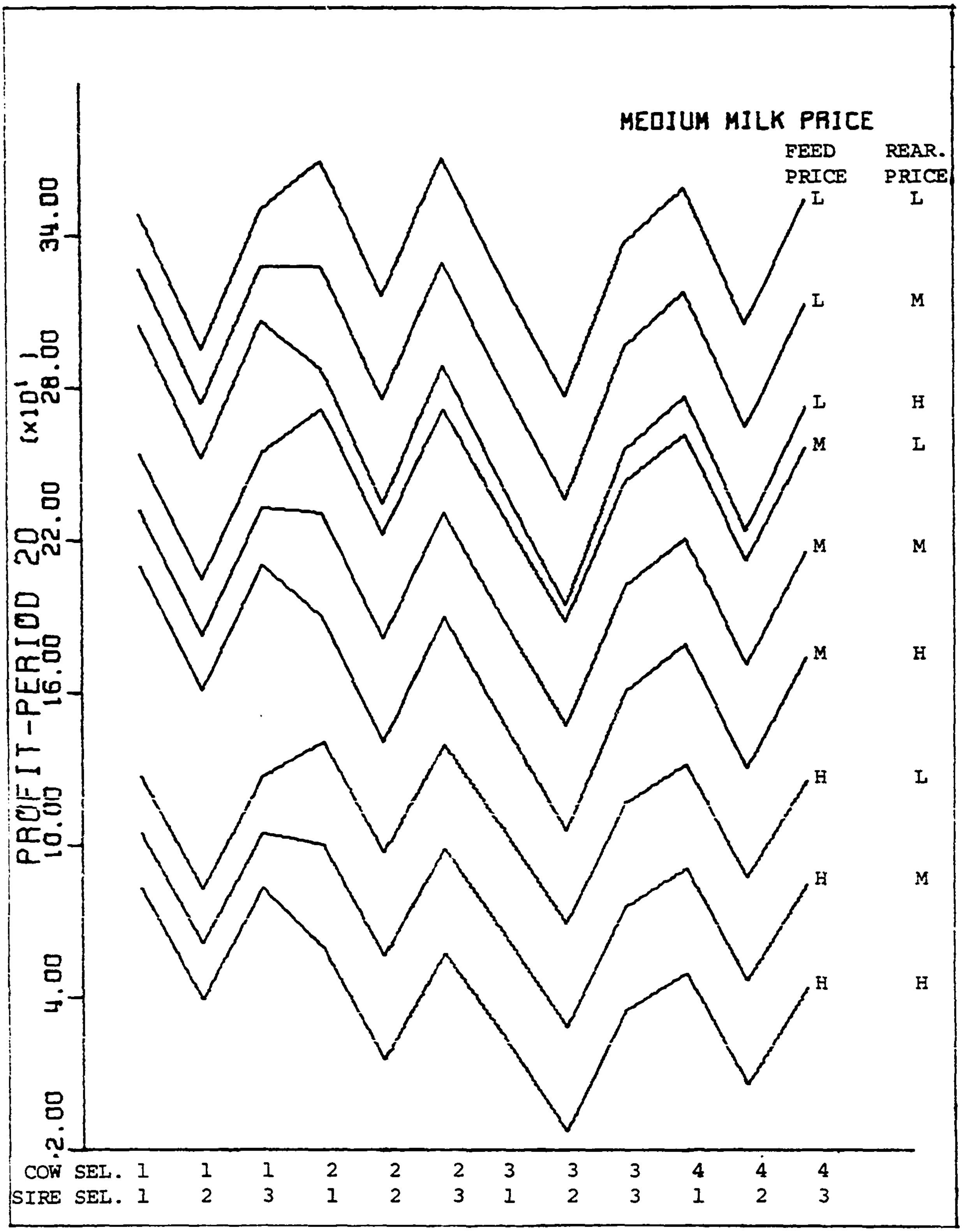


Figure 8. Profit in period 20 per cow at the medium milk price: 40-cow herd, medium-production level

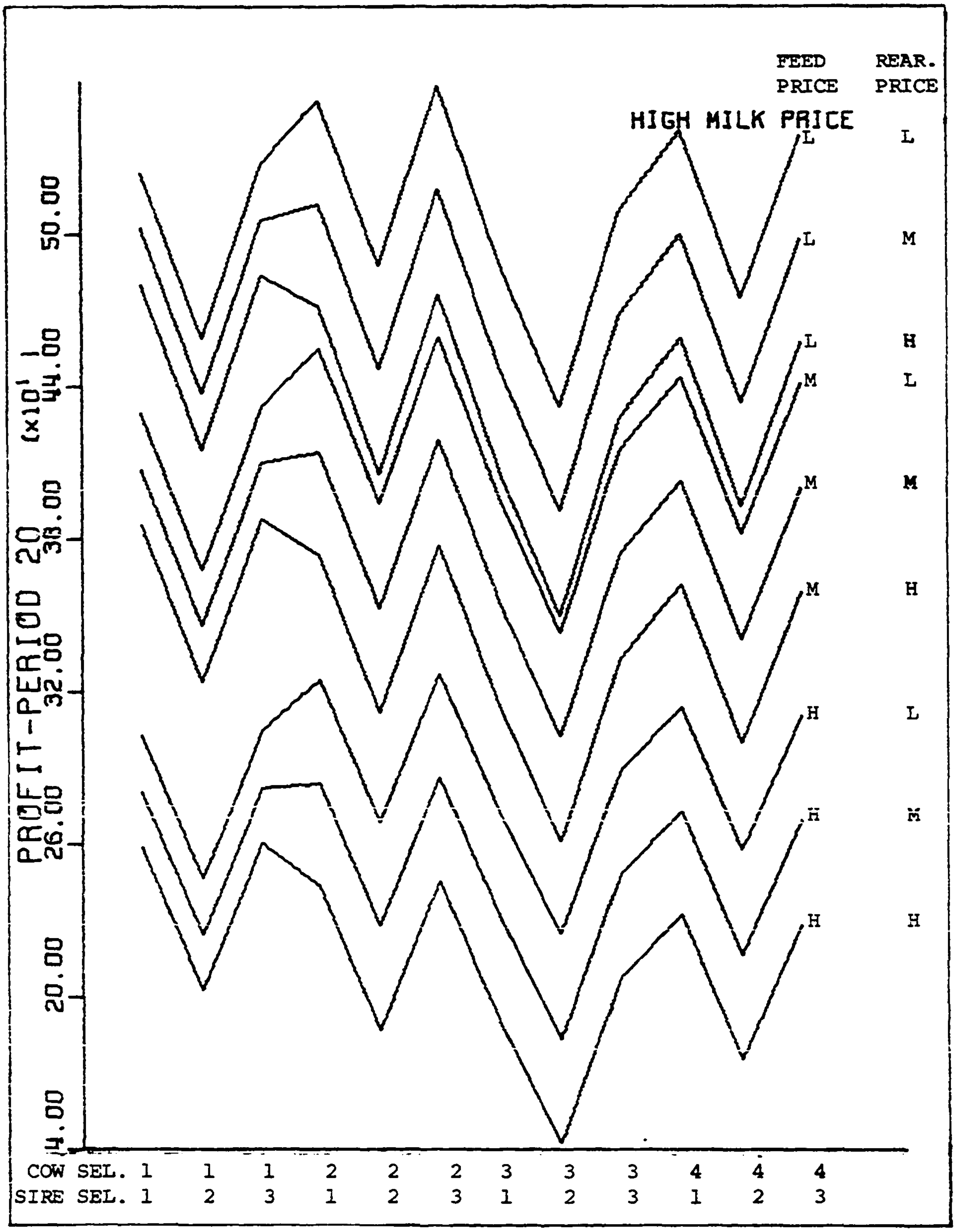


Figure 9. Profit per cow in period 20 at the high milk price: 40-cow herd, medium-production level

be made between system two and sires starting at a higher level but progressing at the same rate, and between system two and a system starting at the same point but increasing at a faster rate. Thus, the poor showing of sire system three during the early periods does not reflect on the fast-gaining system, but rather, on the arbitrary starting point assigned to this system.

For each cow system within a sire system, the only difference between the physical inputs and outputs in period 20 and the average physical inputs and outputs over the 20 periods is in the amount of milk produced. Thus, by evaluating the relative difference in the milk produced in the four cow selection systems, in period 20 and averaged over all 20 periods, differences in the two measures of profit can be explained. Cow systems two through four rank first, third, and second. This is the same ranking obtained for average profit per period. Within sire systems one and two, cow system four has improved its position relative to system two, while system three has lost ground to both systems two and four. Within sire system three, cow system two has improved its relative position over systems three and four about equally. At several of the combination of the economic factors at the high level of production, the profit from cow system three exceeds that from cow systems one and four. This is due to the higher non-milk income for cow system three at the high-production level. The number of price combinations at which this reversal takes place is largest for sire system three. This reversal also occurred for average profit per period.

In period 20, cow system one has improved its relative production position compared to cow system three for sire systems one and two, but has lost part of its advantage with sire system three. Cow systems two and four have increased their advantage over system one, the largest increase coming with sire system three. These changes in production can be followed in Figure 3. Cow system one has higher profit than system three at almost all levels of the economic factors. At the low rearing costs, the profit from period 20 for cow systems one, two, and four rank third, first, and second for all combination of milk and feed price. At the medium rearing cost, cow system one changes rank with changes in the marginal milk price. This cow system ranks highest when the marginal milk price is lowest and ranks lowest when the marginal milk price is highest. Compared to the average profit per period, the profit in period 20 for cow system one is relatively poorer than for systems two and four. This is caused by the decline in the relative production from system one in period 20 compared to the average over all periods. For the herd in Figures 7-9 at the high rearing cost, cow system one still ranks above systems two and four at all levels of the other economic factors even though it has a larger disadvantage in production in period 20 than it has for the average over all periods.

The main effect of each level of the economic factors on profit in period 20 are given in Tables 67-69. This summary of the profit figures for period 20 shows that compared with the average profit over the 20 periods cow systems two and four are comparatively better than system one. This is due to cow selection systems two and four making larger improvement in production than selection system one, especially with sire system three. Also, system three has gained slightly in production level on system one. Thus, system one keeps the same relative position as in the average profit over the 20 periods but its dollar advantage is lowered or its disadvantage is increased. In the comparison of the relative changes from average profit over all periods to profit in period 20, the changes are entirely due to changes in milk production and how it increases income and expenses. The differences between the averages for the herd size, production levels combination are quite comparable to the differences for the average profit over the 20 periods.

Present value of profit

The profit for each of the selection systems, herd sizes and production levels discounted to present value is given in Tables 70-75. As was pointed out in the introduction of this section, the importance of this measure of profit is reduced by the lack of any significant differences in in the initial investment for the different systems and lack of large differences in the rate of change of profit over time for the cow selection systems.

While this measure of profit does not change the relative rank of the sire selection systems, it does bring systems three and two much closer together. The advantage of sire scheme three over scheme two is zero in period one and increases with time. Since the discounting increases with time, the large advantages of sire system three in the later periods do not receive as much weight as the small differences in the initial periods receive. The advantage of sire system three in terms of the present value of the profit is reduced. This is a strong point in favor of choosing sires with as high an initial level as possible, perhaps even to the detriment of a faster gaining sire system. The best system would be to combine the high initial level with the fastest rate of gain possible, thus maximizing present value of profit and other criteria.

The sum of the discount factors, $\sum_{j=1}^{20} \frac{1}{(1+j)^j}$, for the 20 periods is approximately 10. Thus, some indication of the effect of the discounting process can be obtained by dividing the present value of total profit by 10 and comparing this result with the average profit per period. For the 40-cow herd, medium-production level, and the medium level of all economic factors:

Cow sel.	1	1	1	2	2	2	3	3	3	4	4	4
Sire sel.	1	2	3	1	2	3	1	2	3	1	2	3
(a) Total profit/20	173	137	146	170	132	145	136	98	113	159	121	132
(b) Present value/10	155	123	125	152	118	123	119	86	92	141	107	110
(c) Difference (a-b)	18	14	21	18	14	22	17	12	21	18	14	22
(d) Ratio ($\frac{b}{a}$)	89.5	89.4	85.6	89.5	89.2	84.9	87.6	87.9	81.4	88.5	88.2	84.3

The difference between the present value of total profit/10 and the total profit/20 is only effected by the rate of change in profit over the 20 years. When the rate of progress increases with time (curvilinear), the resulting difference between the two measures just discussed is larger than when the rate of increase is constant or decreases with time. For all three forms of the rate of change, increasing rate, constant rate, or decreasing rate with time, the faster the rate of gain the larger the difference between the measures of present value of total profit and average profit per period. The present value of profit/10 can meaningfully be expressed as a percent of the average profit per period only when the profit from all 20 periods is of the same sign. Such is the case for the situation that was given. The ratios of b/a are relative to the gain per period/profit in period one. The lower ratios of b/a for sire system three are due to fast rate of gain and were discussed earlier. The rate of change of profit per period for sire system two was lower than the rate of change for sire system one, but the initial starting point, period one, was also lower for sire system two. The difference between the rates of gain of the different sire system within the cow system also corresponded to the ratios of b/a very closely. The rates of gain are the most different for the three sire systems within cow system three and the ratios b/a are also the most different. The opposite is true for cow system one. As was mentioned, using present value of profit as the criteria of selection favors the system with the higher initial levels and discounts the gain made in later periods.

The present value of total profit for the 40-cow herd at the medium-production level is presented graphically in Figures 10-12. Because the values for sire system three and system two have been pulled closer together, the graphs have a flatter appearance than the graphs of average profit in Figures 7-9. This appearance is partially an artifact dependent upon the order of the selection system combination.

Sire system one yields considerably more profit discounted to present value for each of the cow systems than do sire systems two and three. This is based primarily on the large advantages in the initial production levels for the cows sired by bulls in sire system one. As was discussed earlier in this section, the difference between sire systems two and three have

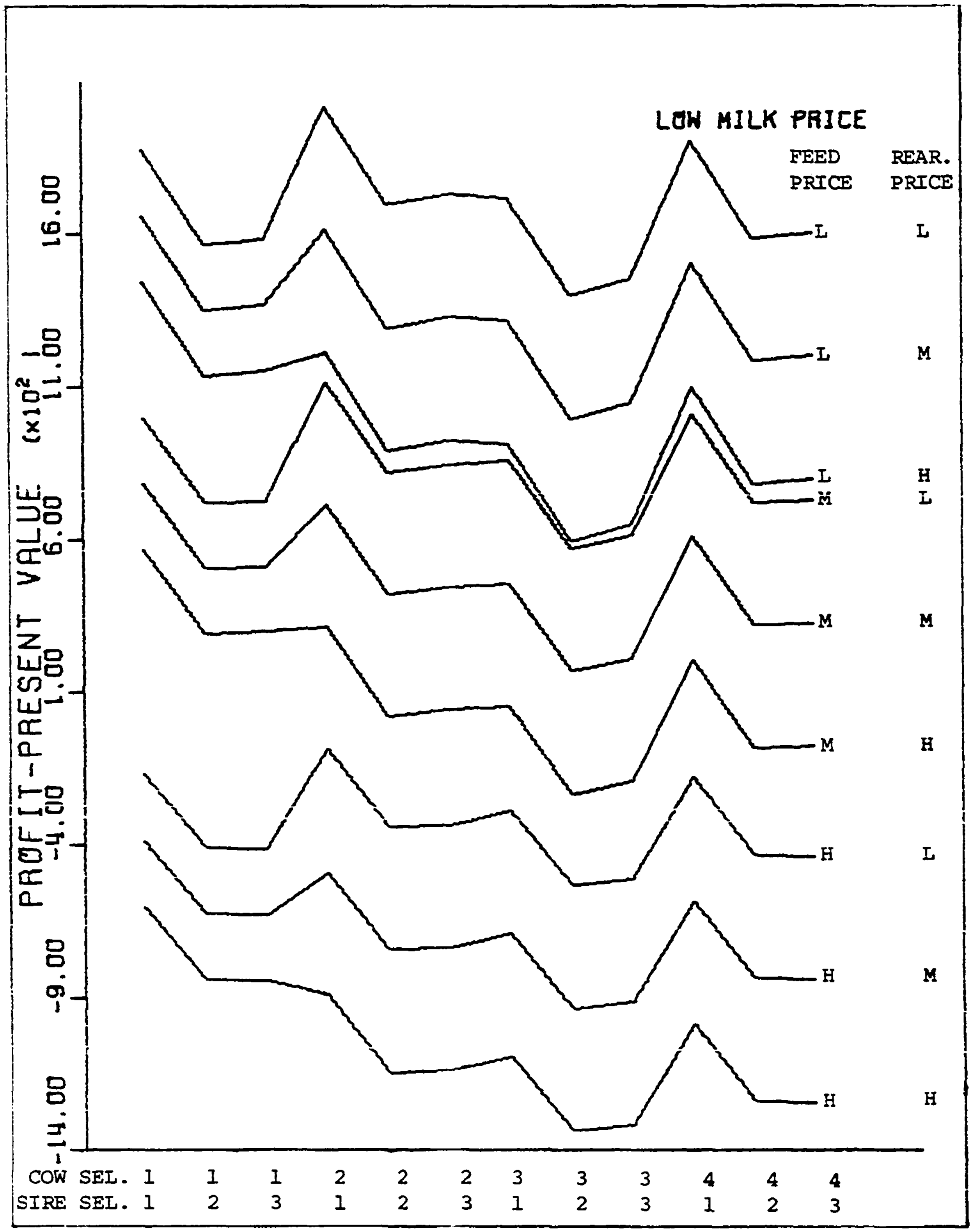


Figure 10. Present value of total profit per cow at the low milk price: 40-cow herd, medium-production level

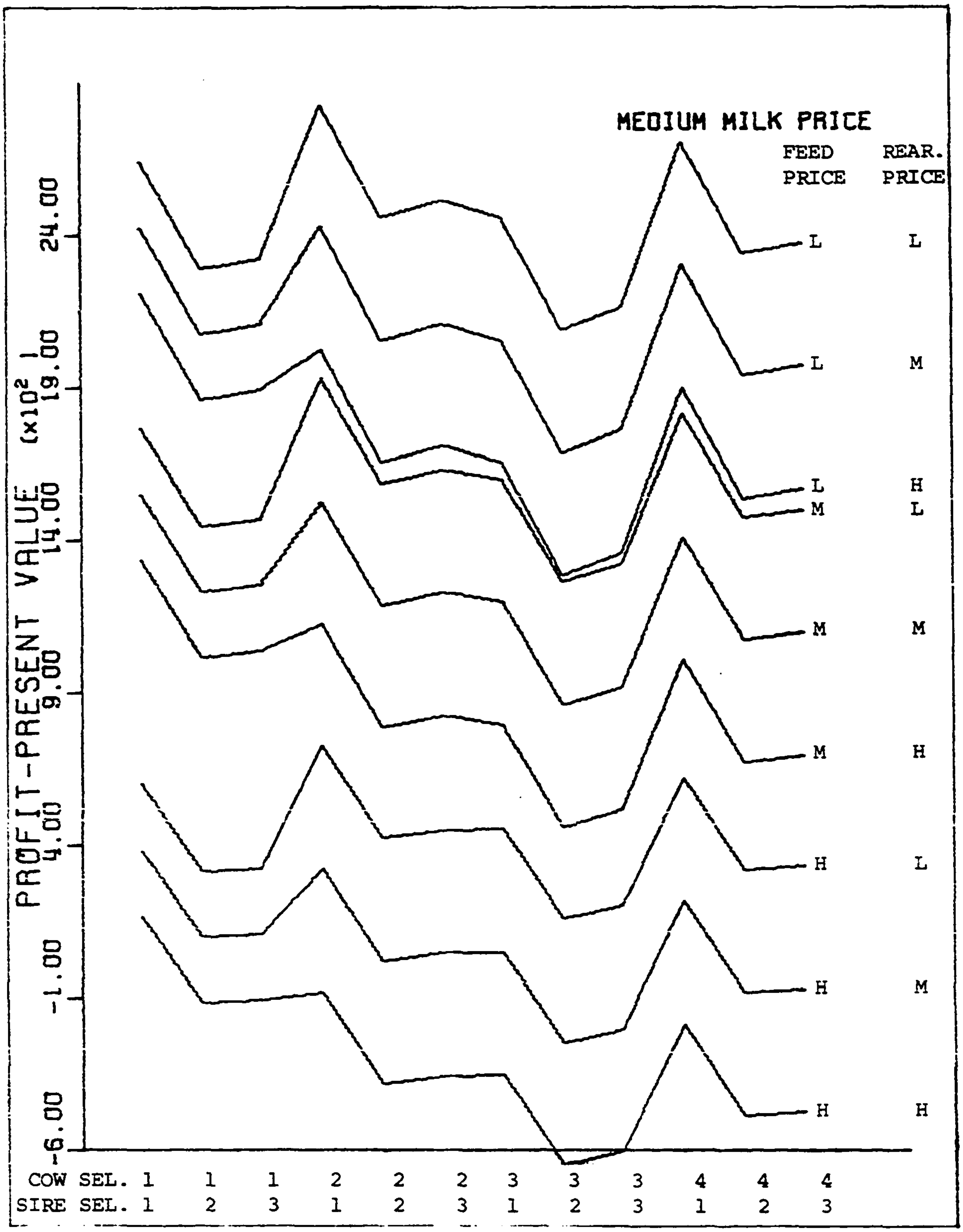


Figure 11. Present value of total profit per cow at the medium milk price: 40-cow herd, medium-production level

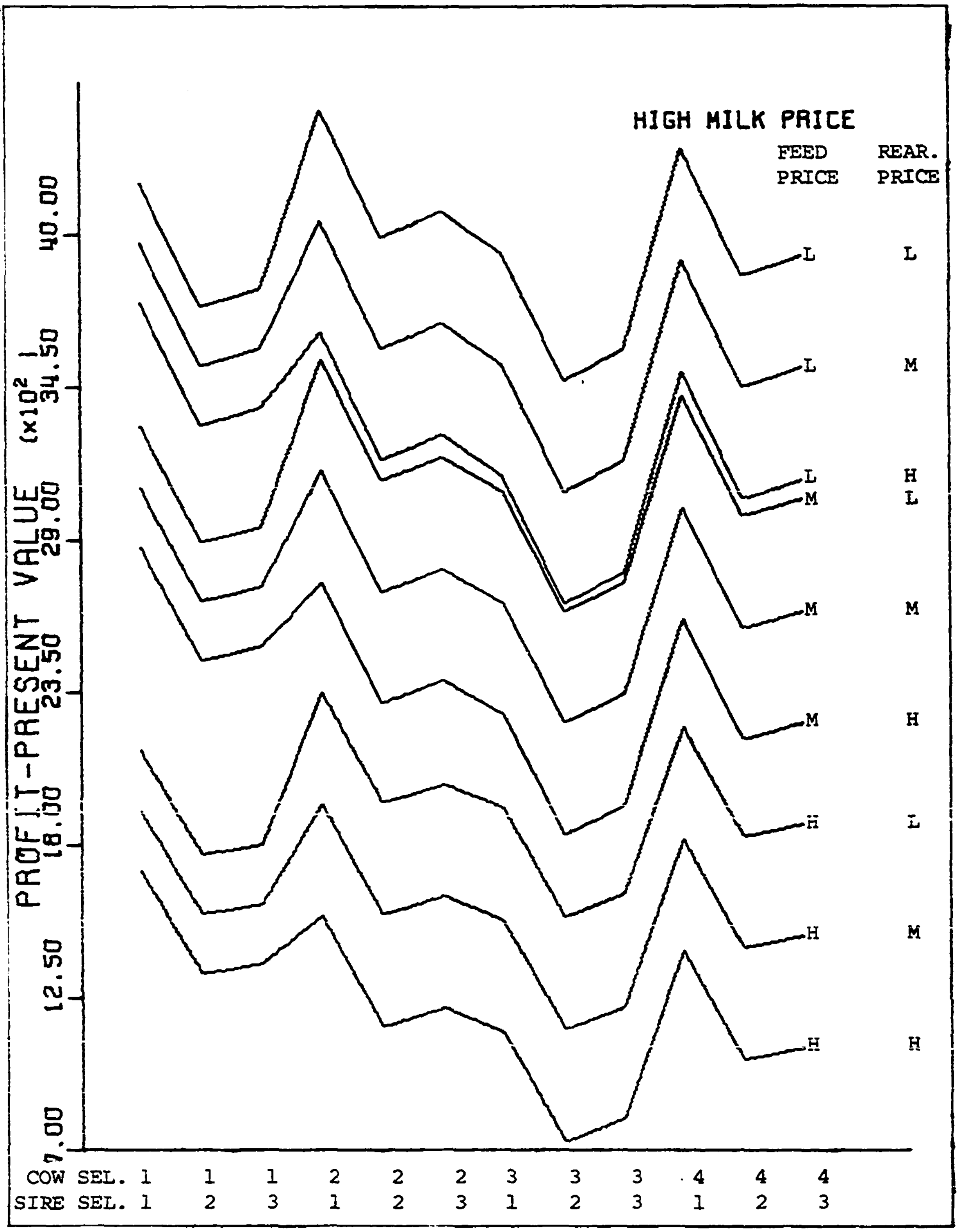


Figure 12. Present value of total profit per cow at the high milk price: 40-cow herd, medium-production level

been almost completely muted.

At the low rearing cost, cow system one yields less present value of profit than either system two or four, while the opposite is true at the high rearing cost. Similarly, the rank of cow system one, two, and four for the medium rearing cost changes with the marginal milk price. This ranking corresponds to the similar economic level for average profit per period and for profit in period 20.

In general, the effect of discounting the total value of profit to present value is to mute the differences which develop with time between the selection systems. Thus, this measure of profit is much more an indication of the starting level of the systems than it is a reflection of the rate of improvement over time. With the small differences between the rate of change of the cow systems and the lack of switch in the order of the systems over time, there are only infrequent changes in the ranking between the three measures of profit, average profit per cow, profit in period 20, and present value of profit. Differences between the sire systems, however, are much larger and thus, the ranking and the distance between the sire systems varies with the particular measure of profit being considered.

The main effects of each economic factor for present value of total profit per cow are given in Tables 76-78. Within a herd size and production level, the same effects described regarding the individual combinations of the economic factors also influence the main effects. The higher the rate of change the greater the effect of the discounting. Differences between the herd sizes for present value of profit divided by 10 are reduced by approximately \$2 to \$5 from the differences between the herd sizes for average profit per period. The corresponding differences between the production levels have also been decreased slightly. The importance of considering the present value of profit would be more evident in comparing different systems if there had been differences in the initial investment needed for the systems.

<u>Change in profit per period</u>

The change in profit per period for the combinations of all of the factors are given in Tables 79-84. A general discussion of this measure of profit will be included before any of the systems are discussed. Change in profit per period was calculated as the regression coefficient of profit on period number. Since the rearing costs do not change from period to period of the same cow system, the rearing cost does not effect the rate of change. This is why change in profit in Tables 79-84 does not vary within a milk and feed price and selection system combination. The rate of change in profit over time is quite dependent on the discrete manner in which the additional cost of high production was included in the simulation and on the number of production "thresholds", 13,000, 15,000, 17,000, and 19,000 pounds, that were crossed and on the position in the 20 periods where the thresholds occurred. The added cost upon crossing the production thresholds is $7, $8, $9, and $10 per cow, respectively. This effect is most important at the higher levels of production, since the additional cost is a function of the pounds of milk. Also, this effect is most obvious when profit per cow is considered rather than the cost per cwt of milk.

Since all of the costs of the dairy operation, other than those associated with the pounds of milk produced are constant for all periods of the same system, they do not affect the rate of change with time. Thus, the rate of change in profit is a function of

pounds of milk x (milk price - feed costs for production - the additional cost of high production)

for each period. If the feed cost per cwt of milk production and the additional cost of high production were constant, the change in profit would be directly proportional to the change in milk production. However, these two expenses are dependent upon the level of production. Feed costs depend slightly on level of production and additional costs for high production are completely dependent upon the the level of production. In Tables 85-90 there are situations where the profit for a period is lower than the profit for the previous period, while there is a corresponding increase in the actual production. This drop is due to the addition of an increment of the cost of high production. This should not be taken as an excuse for excluding the additional cost for high production. This cost is still considered to be valid and could be looked at as the diminishing return for the additional labor, feed, etc. However, it is also obvious that such costs do not occur in the discrete manner in which they were included in this study.

The graphs of the rates of change in profit for the 40-cow herd at the medium level of production are given in Figures 13-15. The highest rates of gain occur with sire system three and they follow the rates of increased milk production fairly closely. The cows from sire system two make the slowest gain in profit and those sired by the bulls in system one are intermediate.

The relative ranking of the cow selection systems within a sire system is variable, it even varies from one production level and herd size to the next. Several effects are the causes of these switches. The first effect

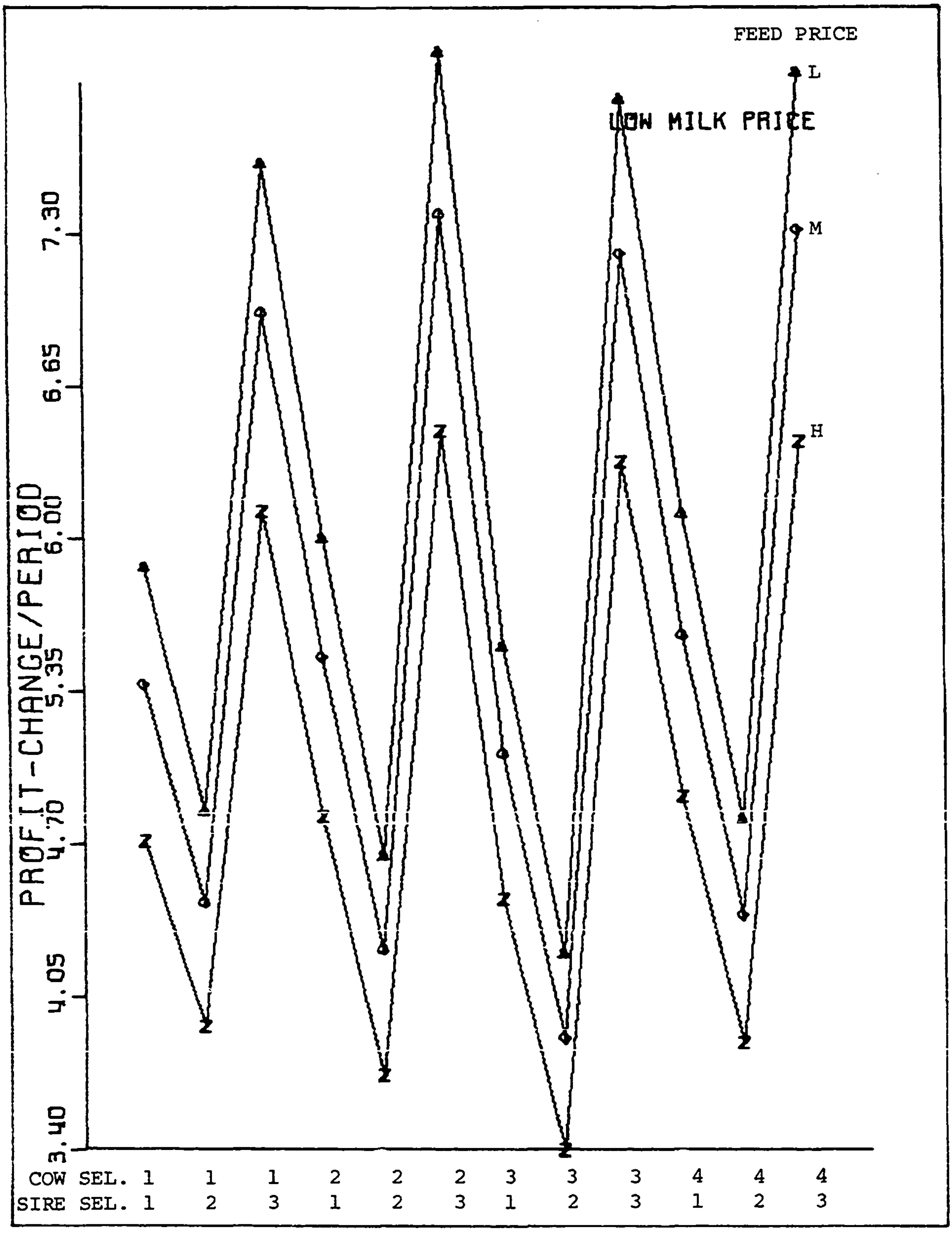


Figure 13. Change in profit per cow at the low milk price: 40-cow herd, medium-production level

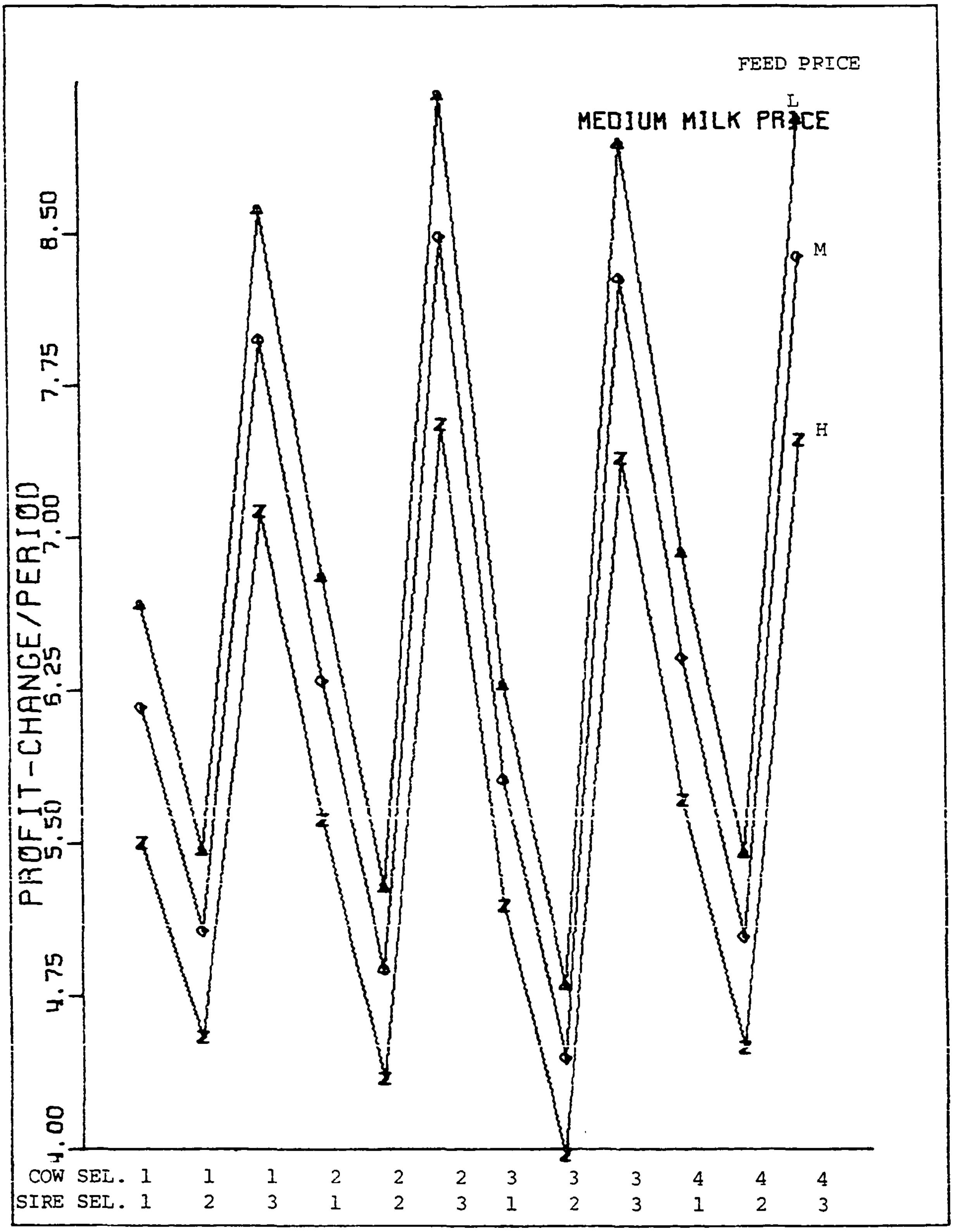


Figure 14. Change in profit per cow at the medium milk price: 40-cow herd, medium-production level

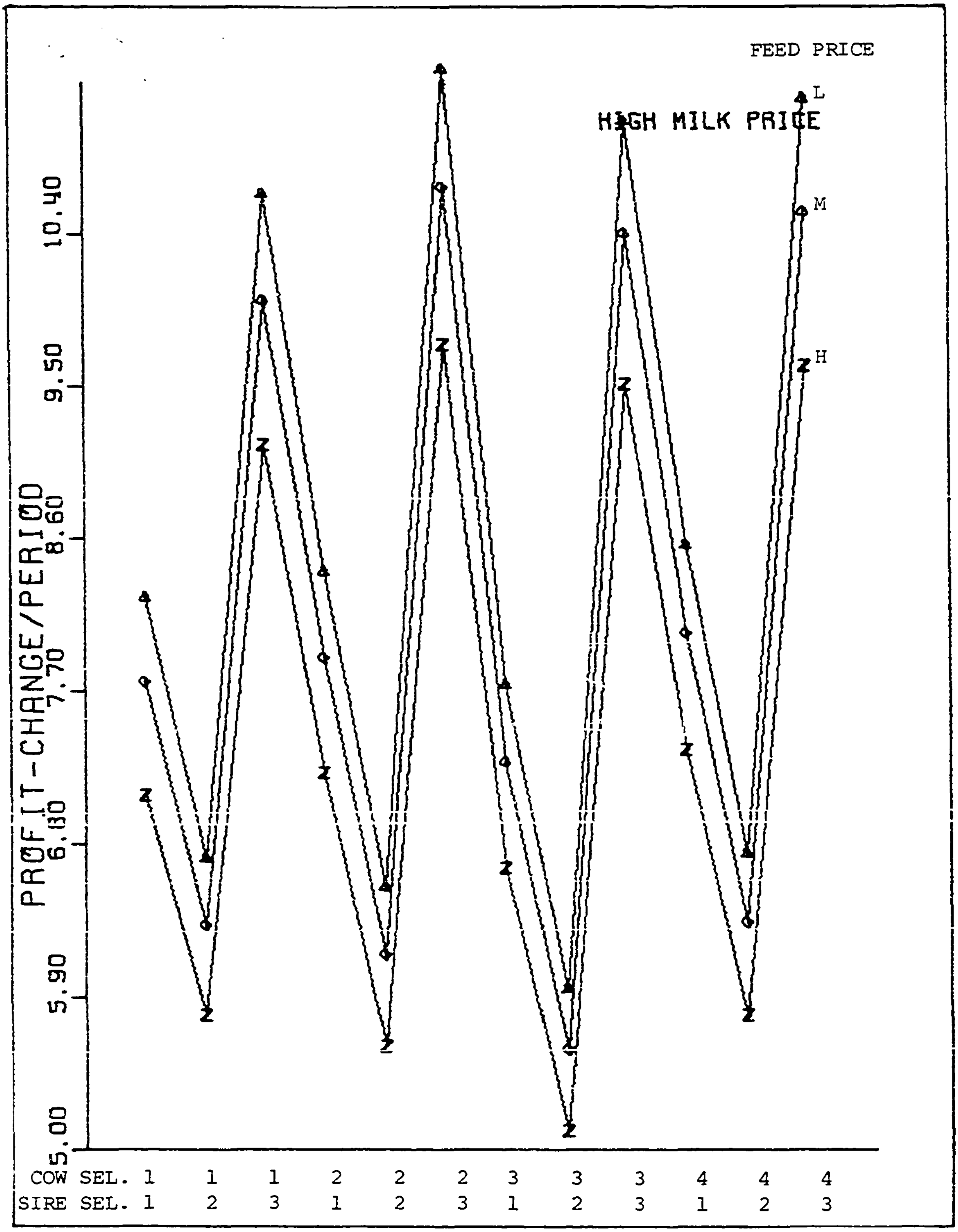


Figure 15. Change in profit per cow at the high milk price: 40-cow herd, medium-production level

is the one that has been stressed earlier, the discrete addition of costs for high production, the number of production thresholds crossed, and the position in the 20 periods where the thresholds occurred. This effect is an artifact caused by the method used for adding the cost and has no basis in the biology or the economics of the situation. However, a second effect is also included, that is the true hypothesized cost due to high production. If the added cost of high production had been added in a continuous manner, the addition of 100 pounds of milk at the 12,000 pound level still would have yielded a larger increment in profit than a similar increase at the 15,000 pound level.

Because of the numerous switches, the cow system will not be discussed for each combination of milk and feed prices but rather will be discussed with reference to the rate of change averaged over economic levels for each herd size and production level, that is, discussion will be limited to the last row of each of Tables 79-84. Several observations about the relative ranking of the selection system can be made. Within sire selection system two, the relative rates of phenotypic improvement of systems one, two, and four are nearly equal, and system three is slower than the other three. Since cow system one is at a lower level of production than system two and four, it is less hindered by the additional cost of higher milk production. Thus, cow system one generally is making the fastest progress, but is closely followed by cow system four. Cow system three is progressing at the slowest rate and cow system two is intermediate between cow system three and cow systems one and four.

Within sire system one, cow system three again progresses at the slowest rate. The other three systems tend to change positions dependent upon the particular herd size or production level being considered. The differences in the order across production levels again represent the effect of additional cost for high production. Cow system four appears to have the edge in most of the herd sizes and production levels. Since this system tends to have the fastest rate of phenotypic gain this effect is probably real.

Within sire system three, cow system one makes the slowest gain in profit. The relative ranking of cow systems two, three, and four varies with herd size and production level. While system two is making the fastest phenotypic gain, it is at the higher level of production where each additional pound of increase brings a smaller increase in profit. System three is making the slowest phenotypic gain of the last three cow systems, but is at the lower level of production where an added pound of milk yields a relatively larger increase in profit. Cow system four is intermediate in rate of phenotypic gain and level of production.

While numerous situations have been mentioned where systems with slower rates of phenotypic gain have been yielding higher rates of gain in profit, resulting from being at the lower level of production, it is only a matter of time before these systems with the slower gain in actual milk production will be at a level of production where they will yield less profit per pound of increase in milk production. Thus, rate of gain in itself is hardly as good an estimate of the value of a system as profit in a specific period, period 20, or even average profit per period. As long as the marginal milk price (milk price - feed cost for production - additional cost for high production) is positive, however, it will be beneficial to increase milk production. At the lowest milk price and the highest feed price and the highest addition cost for high production hypothesized in this study, the marginal milk price/cwt is considerably above zero, approximately

$$5.00 - 1.50 - .20 = 3.30.$$

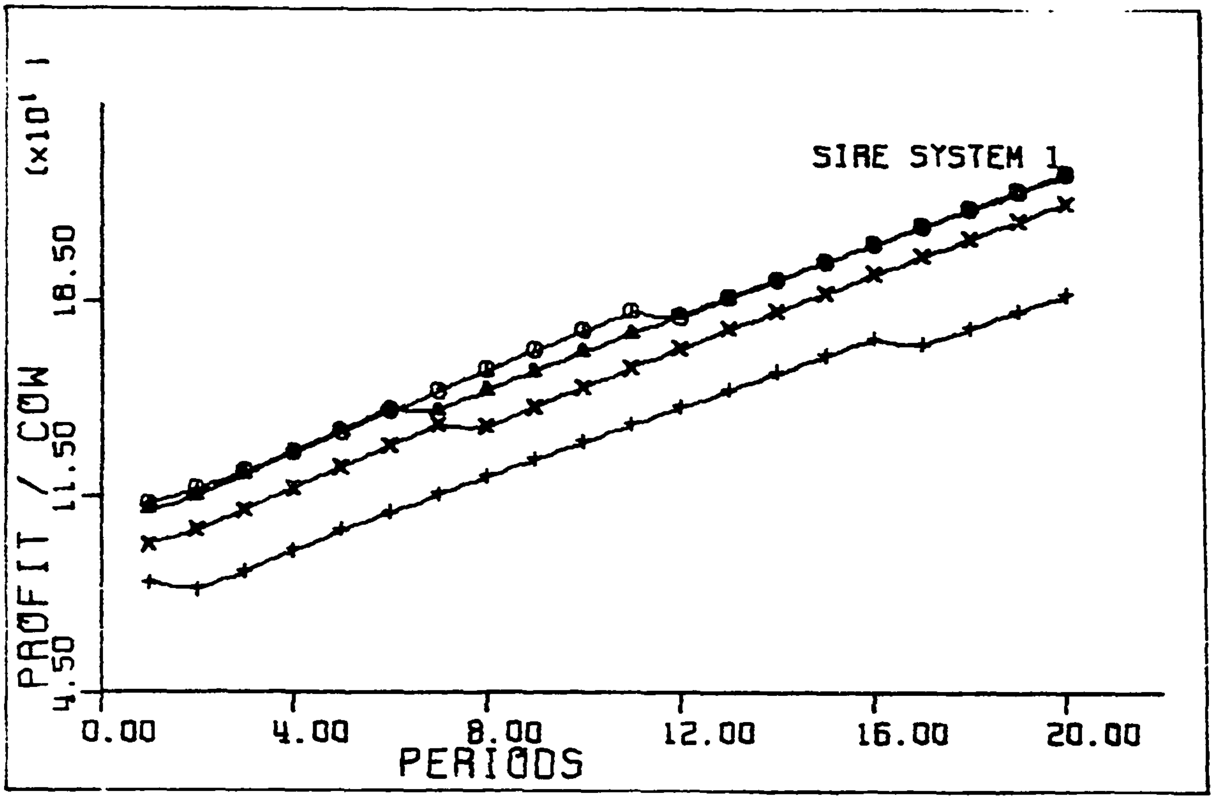
Thus, under the current milk price levels, added costs above the ones used here would need to be very large before milk production at other than the highest level possible would maximize profit. The additional costs of production that were used cannot be well documented. However, it can be seen that the $.20 addition cost, in the previous example, would have to be much greater in magnitude to negate the $3.30 marginal profit per hundred pounds of gain in milk.

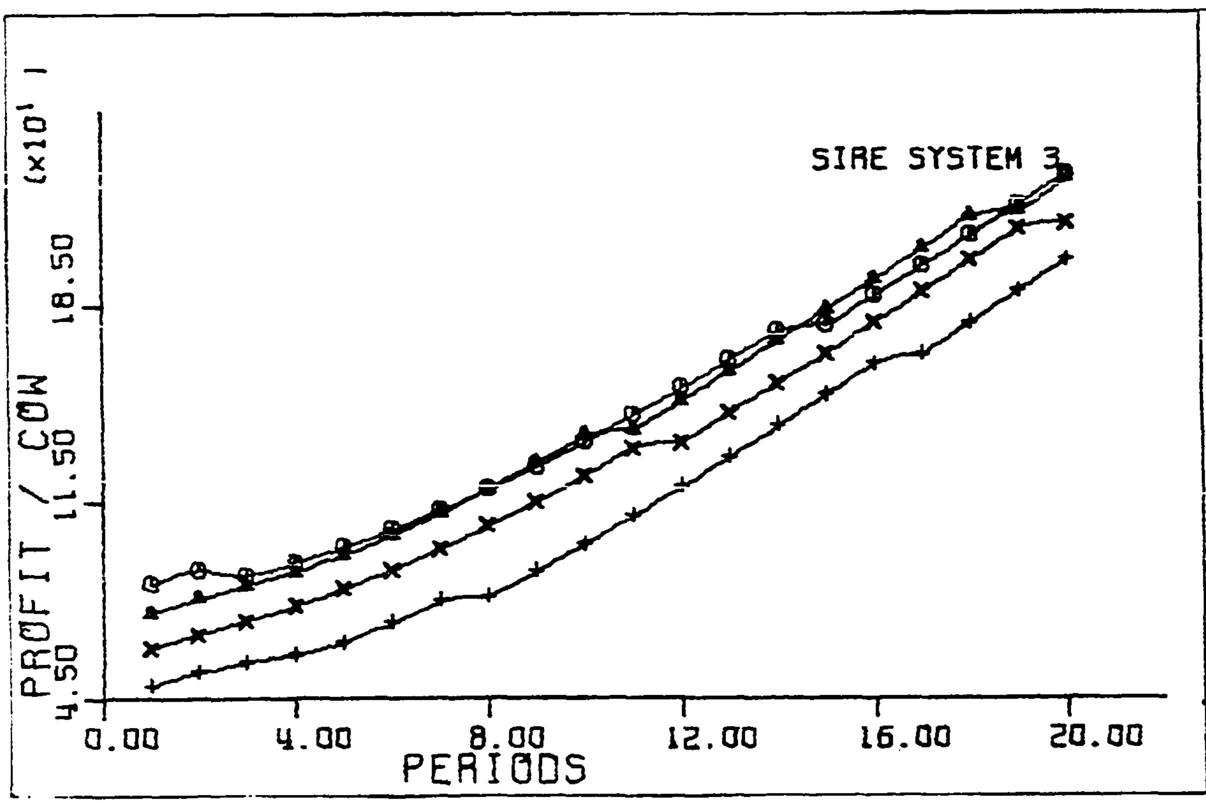
Trends over time of profit at the medium level of the economic factors

The average profit per cow at the medium levels of the economic factors for each selection system, herd size, production level for the 20 periods are presented in Tables 85-90. There is a tremendous range in profitability at the different production levels and herd sizes and for the different cow and sire selection systems, within a constant milk and feed price and the rearing cost. The differences between the two herd sizes are due mainly to decrease in labor and fixed costs per cow as the herd size increases from 40 to 120 cows, and is nearly constant at $95 across the 20 periods. The increase in the profit from one production level to the next is attributable to the increase in the value of the milk produced minus the variable costs for producing the added milk (additional feed cost and the increase in the other cost of producing milk at the higher level of production). These differences are also fairly constant over the 20 periods with the exception of periods where an additional increment of cost for high production was added.

The profit per cow at the medium level of the economic factors for the 40-cow herd and the medium-production level are given in Figure 16. The rather sudden shifts in the curve for each cow selection system are due to the additional cost of milk production being applied in a discrete rather than continuous fashion. Within sire selection systems one and two, cow selection systems one, two, and four progress at about the same rate, while system three progresses at a slightly slower rate. To the large extent, these profit figures at the medium level of the economic factors follow the actual milk production figures. However, the level of profit from cow system one is more nearly alike system two than the production figures suggest. This is due to the lower rearing costs for system one, since only one-half the number of heifers are raised in system one that are raised for the other systems. Within sire system three, the profit figures follow the same curvilinear relationship that the production figures followed. With the exception of the profit for cow system one, the profit for the other systems follow closely the relative production levels.

In evaluating the long term effects of the four cow selection programs on profit, several conclusions can be reached. Cow selection system three, where there is no voluntary culling on production, is not a profitable culling system even when the sound cows that are culled are sold for a reasonable premium above beef prices. Thus, this system cannot be recommended. Cow selection system four, all voluntary culling practiced on two year olds, yields slightly less production than cow system two and is thus slightly less profitable. Over time, cow system four is gaining on system


SIRE SYSTEM 1
PROFIT / COW
(x10¹)
4.50
11.50
18.50
0.00
4.00
8.00
12.00
16.00
20.00
PERIODS


SIRE SYSTEM 3
PROFIT / COW
(x10¹)
4.50
11.50
18.50
0.00
4.00
8.00
12.00
16.00
20.00
PERIODS

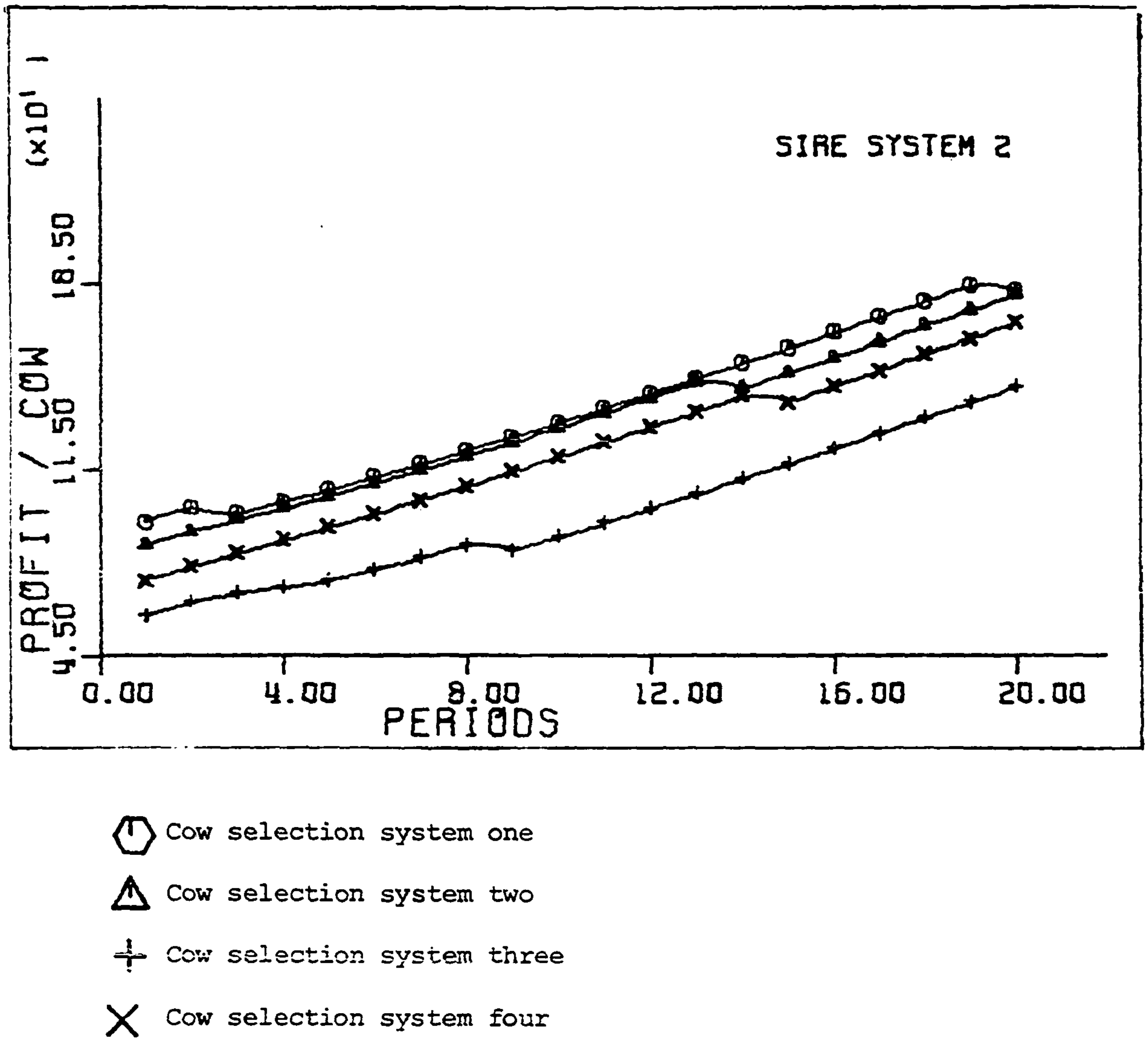


Figure 16. Profit per cow for each of the 20 periods at the medium level of all economic factors: 40-cow herd, medium-production level

two in both production and profitability. Cow system two has the highest milk production for the 23 years of the study. It is the most profitable at low rearing costs. Cow system one is marginal in milk production and varies in its rank on profitability. This cow system makes only slightly less gain in milk production than systems two and four when the breed-average or high AI sires are used. However, with the fast-rate-of-gain sires, this is the slowest gaining system. At the high rearing cost this cow system would maintain a profit advantage over all other systems for quite a number of years. At the low rearing cost the system has little advantage. At the medium rearing cost the system will continue to be competitive with systems two and four past the range of this study at the only lowest marginal milk prices.

General Comments

The validity of this study is dependent on the parameters used. These parameters can be broken down into three groups: genetic and phenotypic parameters, age-related parameters, and income and expense parameters.

The genetic and phenotypic parameters are probably substantiated best in the literature. There have been many studies in which heritability (h^2) and repeatability (r) have been estimated. The affect of any differences between the true parameters and the ones used would effect each of the selection systems slightly differently. The phenotypic and genotypic levels of cow system three are unaffected by the estimates of h^2 and r that were used, while cow system one is only slightly effected by the estimate of r that was used. Based on the size of differences noted in the literature, very few changes in the ranking of the systems would occur due to improper estimates of h^2 and r.

Age correction factors determine the age-production relationship in this study. Because of the differences in the age distribution of the selection systems, age factors affect each cow selection system differently. The magnitude of this effect can be judged relative to the age distributions of the cow selection systems. There is strong indication in the USDA age correction factors (McDaniel et al., 1967) that there are real differences in the age-production relationship for the different areas of the country. However, only one age-production relationship was used in this study.

The involuntary losses in the cows and the percent of the heifers born that survive to enter the milking herd with no culling, are the major determining factors of the intensity of the selection that can be practiced. These affect each culling system slightly differently. In this study, the percent of heifers born that survive to enter the milking herd was varied with production level and herd size.

The income and expense items related to the dairy herd have two parts: the amounts of the physical items that are needed, and the unit prices of these items. These amounts and prices were based on reports from experiment station bulletins, other research publications, popular articles, reports from statistical reporting services, and knowledge of the dairy operation. In reviewing the income and expense items, several things should be pointed out:

1. Feed cost included the total cost of feed production, operating costs and fixed costs including the cost of ownership of the land.
2. Labor cost included only that labor used directly in the milking

operation. This did not include the labor used in calf rearing or feed production, but did include labor for caring for milking and dry cows and the labor used for feeding, milking and the other duties directly associated with the herd.

3. Fixed cost included only those items directly associated with the milking herd and did not include the fixed costs for feed production or rearing heifers.
4. Rearing cost included all the costs of rearing the heifer from birth to freshening, but do not include the value of the calf.
5. The price for heifer calves, bull calves, and cull cows were all fixed at prices near what is now being paid.

Prices for the income and expense items were held constant for the 20 periods. It is reasonably certain that this is not apt to be absolutely realistic. However, if the relationship between expenses and income changes proportionally, the assumption of constant prices will not effect the ranking or the relative distance between systems.

While changes in the physical units of different items needed to operate the dairy herd have been observed over time, less labor, more mechanization, etc., the physical inputs are much less subject to change than are the prices. Also, changes in the physical inputs tend to change in a more gradual way over time and lack the extreme peaks and valleys of the prices.

The prices which have the greatest effect on the profit of the systems, milk price, feed price, and rearing costs, have been included in this study at three different levels which encompass most of prices experienced in the Midwest. Several prices which affect profit of the systems differently, but are not a major source of variation have been included at only one level. Non-variable costs dependent upon herd size were only included at one level for each herd size. For the individual trying to predict the profit under a specific culling scheme, any differences from the non-variable costs/cow given in this study can be added or subtracted from the profit given for that system.

The least substantiated parameters used in this study deal with production level. The basis of determining feed cost per pound of milk for herds which are genetically quite similar but which are phenotypically quite different is nearly non-existent. The only difference included in this study was the slight additional feed recommended for high levels of feed intake by the NRC feed requirements for dairy cattle. This is probably a minimum adjustment for the situation described, however, there is little other quantitative basis for such an adjustment in the literature. The second parameter associated with production level which can not be well substantiated is the additional cost for higher levels of milk production. The levels used are little better than an educated guess. It does seem reasonable that as production increases there are increases in the variable costs which are not accounted for. Some of these include labor, veterinary costs, higher quality and thus higher costs for feed, and miscellaneous other costs. Because of the lack of substantiation of these parameters possibly the least reliable comparisons are those between production levels. Even if the parameters for production levels are in error, the size of the differences in profit between production levels would still be substantial.

Because of the nature of the sire and cow selection combinations, there are interactions between the combination for production traits. The models used to generate the data were all additive. However, interactions in profit for the different systems at different price level combinations also occurred. These result from income and expense being the sum of several items on which the price and physical quantities are subject to change for the different systems.

This study was conducted with the assumption that all selection was truncation selection. Deviations from truncation selection would tend to bring the production levels of systems one, two, and four closer to system three. These deviations would probably be most deleterious to system two and four and to a lesser extent to system one. If selection was for traits other than milk production, the relative changes in the profitability of the selection systems would be strongly dependent upon the economic worth of the additional traits selected.

Further work to determine the quantitative effect of different involuntary losses in the cows and in the calves, the effect of different age-production relationships, and the effect of selection for milk production along with other traits is needed. Also, the possibility of selling some cows for dairy purposes might be included. It is evident that some basic work is needed to quantitate the reasons that herds of genetically similar levels produce at vastly different levels.

Several other considerations need to be discussed. The variation in the sex ratio and in the involuntary losses from year to year have not been included. That is, fixed involuntary losses and sex ratios were used for all 20 periods of all systems. These two variables would limit the degree to which cow system one could be followed. The closest that one could practically follow system one would be to raise several more heifers than are thought to be needed. This would reduce the size of the advantage that the system has in total rearing costs. Variation in these variables would affect the other three systems but, would not have as obvious an effect on the profit from these systems as it would on system one.

SUMMARY AND CONCLUSIONS

Summary

This study was undertaken to determine the effect of several cow selection systems on the profitability of the dairy herd. The four selection systems were: (1) all voluntary selection on calves, only enough females raised to replace involuntary culls; (2) selection based on the average of the cow's records; (3) selection of the youngest cows possible; and (4) selection only during the first lactation based on estimated breeding value. Systems two through four freshen all females. Three sire selection schemes were used in combination with the cow system: (1) high AI sires, (2) breed-average sires, and (3) fast-rate-of-gain sires.

Deterministic models were used to simulate the genetic and phenotypic production levels for the cow and sire combinations over 20, 13-month periods in two herd sizes and at three production levels. Physical input and output items, other than milk production, were included based on the specific cow systems and on estimates of the needed quantities from the literature. The age distributions of the various cow systems were calculated from formulae developed in this study. These formulae depend on the herd size, the involuntary losses in the cows at each age. The parameters of phenotypic and genotypic gain were developed from the selection intensities, and the accuracy of selection where possible. One system (cow system two) involved multistage selection, and a simulation procedure was used to estimate the parameters for this system.

The genetic average for period 20 and the regression estimate of genetic gain over the 20 periods on a HE basis are summarized below for the

12 combinations of the selection systems for the 40-cow herd, medium-production level.

Genetic levels - heifer equivalent basis

	Sire systems							
	1		2		3		Average	
Cow system	Gain/ period	Period 20	Gain/ period	Period 20	Gain/ period	Period 20	Gain/ period	Period 20
1	123	13,659	97	12,740	159	13,868	126.3	13,434
2	125	13,761	99	12,778	174	14,110	132.7	13,549
3	117	13,444	92	12,453	171	13,865	126.7	13,254
4	124	13,766	99	12,799	167	14,019	130.0	13,528
Ave.	122.3	13,666	96.8	12,693	167.8	13,965	129.0	13,441

The DHI averages for period 20 and the regression estimates of gain in the actual DHI levels over time for the 40-cow herd, medium-production level for each combination of the selection systems are given below.

DHI levels - actual production

	Sire systems							
	1		2		3		Average	
Cow system	Gain/ period	Period 20	Gain/ period	Period 20	Gain/ period	Period 20	Gain/ period	Period 20
1	147	16,330	116	15,190	188	16,501	150.3	16,007
2	149	17,113	118	15,948	204	17,487	157.0	16,849
3	136	15,595	106	14,445	197	16,063	146.3	15,368
4	152	16,969	120	15,797	199	17,215	157.0	16,660
Ave.	146.0	16,502	115.0	15,345	197.0	16,817	152.7	16,221

These tables provide the data to make comparisons between the genetic and phenotypic levels of the selection systems.

The physical inputs and outputs from each herd period were evaluated economically. Fixed prices were used for many of the expense and income items, however, the milk produced, the feed used, and the heifers raised were evaluated at three levels of milk price, feed price, and rearing costs. The profit figures for four measures of profit, average profit per period, profit in period 20, present value of profit, and the regression of profit on time are summarized at the medium levels of milk price, feed price, and rearing costs for the 40-cow herd at the medium-production level.

Four measures of profit - medium level of all economic factors

	Sire system							
	1		2		3		Average	
Cow system	Period 20	Gain/ period	Period 20	Gain/ period	Period 20	Gain/ period	Period 20	Gain/ period
1	231	6.17	182	5.07	232	7.98	215.0	6.41
2	320	6.29	181	4.88	230	8.48	213.7	6.55
3	187	5.81	146	4.45	201	8.28	178.0	6.18
4	220	6.40	170	5.04	215	8.39	201.7	6.62
Ave.	217.0	6.16	169.8	4.86	219.5	8.26	202.1	6.43

Cow system	Sire system 1 Ave. profit	1 Present value ÷ 10	2 Ave. profit	2 Present value ÷ 10	3 Ave. profit	3 Present value ÷ 10	Average Ave. profit	Average Present value ÷ 10
1	173	155	137	123	146	125	152	134
2	170	152	132	118	145	123	149	131
3	136	119	98	86	113	92	116	99
4	159	141	121	107	132	110	137	119
Ave.	160	142	122	109	134	113	139	121

The average profit and the profit in period 20 from each of the culling systems for the 40-cow herd at the medium-production level were summarized over all combinations of milk and feed price for each level of rearing cost. These summaries provide the most relevant comparisons of the selection systems.

Low rearing cost

Cow system	Sire system 1 Ave. profit	1 Period 20	2 Ave. profit	2 Period 20	3 Ave. profit	3 Period 20	Average Ave. profit	Average Period 20
1	211	271	174	221	184	273	190	255
2	229	291	190	240	203	291	207	274
3	192	246	153	203	170	261	172	237
4	218	280	179	229	190	275	196	261
Ave.	213	272	174	223	187	275	191	257

Medium rearing cost

Cow system	Sire system 1 Ave. profit	1 Period 20	2 Ave. profit	2 Period 20	3 Ave. profit	3 Period 20	Average Ave. profit	Average Period 20
1	189	249	152	199	162	251	168	233
2	188	250	149	199	162	251	166	233
3	151	205	112	162	129	220	131	196
4	177	239	138	188	149	234	155	220
Ave.	176	236	138	187	151	239	155	221

High rearing cost

Cow system	Sire system 1 Ave. profit	1 Period 20	2 Ave. profit	2 Period 20	3 Ave. profit	3 Period 20	Average Ave. profit	Average Period 20
1	167	227	131	177	141	229	146	211
2	147	209	108	158	121	210	125	192
3	110	164	71	121	88	179	90	155
4	136	198	97	147	108	193	114	179
Ave.	140	200	102	151	115	203	119	184

These figures have summarized the phenotypic, genotypic and profit results from the 12 combinations of the selection systems. While there are interaction at combination of the other economic factors, the main effects of rearing costs are by far the most important. Specific comparison of the cow culling schemes are given in the conclusions that follow.

Conclusions

1. Considerable culling on production can be done without extending the generation interval much beyond its minimum (compare cow systems two and three). This is because of the increasing involuntary losses with increasing age.

2. The generation interval of the cows is more important in affecting genetic gain at the fastest rates of gain in the sires, than in slower rates of gain in the sires.

3. With the involuntary losses and the age-production relationships used in this study, there is a sizeable difference in the actual milk production between the oldest and youngest age distributions possible, contrary to the results of Rendel and Robertson (1950).

4. The build-up of permanent environmental effect is an important source of phenotypic improvement in the cows selected when selections are made on the cow's own records.

5. The level of rearing costs exert a major effect on the profitability of the different systems, because of the difference in the number of heifers raised with the different culling systems.

6. An increase in milk production of a system in two periods of time will yield an increase in profit equal to: (actual milk production x the marginal milk price) in time period two - (actual milk production x the marginal milk price) in time period one, where the marginal milk price equals (the milk price - feed cost for production - additional cost for high production). The gain in profit is not completely proportional to the gain in milk production, since the marginal milk price decreases as production level increases. However, with the parameters used in this study, it

is highly profitable to produce at the highest level possible.

7. Cow systems two and four produce the fastest genetic gain, phenotypic gain, and the highest actual production of the four cow systems. Cow system two being best in genetic improvement and level of actual production and system four being best in phenotypic gain for sire systems one and two.

8. Cow system one yields slightly less genetic and phenotypic gain than systems two and four with sire systems one and two and is lowest in genetic and phenotypic gain for sire system three. The actual production levels for cow systems one are intermediate to cow systems two and four and cow system three.

9. Cow system three has the lowest level of actual production with all sire systems and the lowest rates of genetic and phenotypic gain with sire systems one and two. With sire system three, cow system three yields the second highest genetic gain and the third highest phenotypic gain.

10. With the type of AI sires now available either cow systems two or four would be quite comparable for producing genetic and phenotypic improvement. Cow system one would be intermediate, but fairly acceptable. Cow system three would produce the least improvement and does not seem to be an acceptable system for genetic or phenotypic improvement.

11. Cow system one produces the highest profit at the high rearing costs at all levels of the other economic factors. At the low rearing cost system one produces more profit than system three, however, its advantage is being reduced within sire system three. Cow system one yields less profit than cow systems two and four. At the medium rearing cost, the rank of cow system one is dependent upon the other economic factors. Because of the lower level of milk production of system one, this system is compara-

tively best with the lower marginal milk prices.

12. Cow system two yields the highest profit at the low levels of rearing cost and is second high at the high level of rearing cost. At the medium rearing costs, this system ranks first or second dependent upon the level of milk and feed price. Because of its superiority in milk production, the system yields higher profit with the higher marginal milk prices.

13. Cow system three yields the lowest profit at almost all levels of the economic factors. Only at the high level of production where cows sold for dairy purposes yield $125 above beef prices is this system at all competitive. Even here, it has next to the lowest profit.

14. Cow system four has slightly lower profit than system two for all levels of the economic factors, and ranks just below system two at all levels of rearing cost.

15. For sire systems one and two the rank of the cow systems on the three measures of profit, average profit per period, profit in period 20, and present value of total profit does not change. For sire system three the rank does not change, but cow systems one loses ground and cow system three gains slightly over time.

General Recommendations

1. At low levels of rearing cost a system comparable with cow system two would produce the greatest genetic gain, highest level of milk production, and the most profitable dairy herd.

2. At high levels of rearing cost, culling the poorest calves but allowing some reserve to be able to maintain a constant herd size would yield the highest profit, but would not produce the highest DHI average or

the highest rate of genetic gain.

3. At intermediate levels of rearing cost, there appears to be justification for culling a small proportion of calves on estimated breeding value with the remaining culling being done on cows in the milking herd regardless of age.

4. At all levels of the economic factors, use of the highest AI proven sires available is strongly recommended. This source of genetic and phenotypic gain is considerably more important than the type of cow culling scheme used.

All of the recommendations and conclusions are based on the assumption that the parameters used in this study are correct or at least are not significantly in error.

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APPENDIX

TABLE 33. GENETIC LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, LOW-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		11254	10754	10754	11271	10771	10771	11102	10602	10602	11283	10783	10783
2		11349	10849	10849	11365	10865	10865	11197	10697	10697	11378	10878	10878
3		11486	10942	10942	11537	10959	10959	11342	10764	10764	11551	10973	10973
4		11628	11035	11045	11703	11054	11071	11494	10831	10848	11695	11071	11088
5		11769	11131	11161	11860	11153	11202	11650	10901	10953	11840	11170	11214
6		11910	11228	11288	12009	11254	11348	11778	10990	11096	11983	11271	11352
7		12049	11327	11426	12153	11356	11506	11908	11080	11249	12125	11373	11500
8		12187	11427	11575	12291	11460	11674	12037	11173	11414	12263	11476	11658
9		12321	11529	11733	12424	11565	11851	12161	11270	11590	12399	11580	11825
10		12452	11632	11900	12554	11671	12036	12282	11371	11775	12532	11686	12000
11		12580	11736	12074	12681	11779	12226	12402	11473	11967	12660	11792	12181
12		12705	11841	12254	12805	11886	12421	12520	11577	12164	12786	11899	12368
13		12828	11947	12439	12927	11995	12621	12637	11682	12366	12909	12007	12560
14		12950	12054	12628	13047	12104	12824	12752	11789	12572	13031	12115	12756
15		13071	12161	12821	13166	12213	13029	12867	11897	12780	13152	12224	12955
16		13190	12269	13018	13284	12323	13238	12981	12005	12991	13271	12333	13157
17		13309	12377	13218	13400	12433	13448	13095	12114	13203	13389	12442	13361
18		13426	12486	13421	13516	12543	13660	13208	12223	13417	13506	12552	13568
19		13543	12595	13626	13631	12653	13873	13321	12333	13632	13623	12662	13777
20		13659	12704	13832	13745	12764	14087	13433	12443	13848	13738	12772	13987
CHANGE/PERIOD		128	102	165	130	105	179	123	97	177	130	105	172

TABLE 34. GENETIC LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, MEDIUM-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		11385	10885	10885	11393	10893	10893	11223	10723	10723	11410	10910	10910
2		11480	10980	10980	11487	10987	10987	11318	10818	10818	11505	11005	11005
3		11608	11063	11063	11643	11062	11062	11446	10866	10866	11663	11083	11083
4		11739	11147	11157	11794	11142	11160	11580	10912	10930	11797	11170	11188
5		11871	11233	11262	11938	11228	11278	11715	10963	11017	11932	11260	11304
6		12003	11321	11381	12076	11318	11413	11835	11044	11152	12066	11351	11433
7		12134	11411	11510	12210	11411	11563	11956	11125	11297	12198	11445	11574
8		12263	11503	11651	12341	11507	11725	12076	11210	11454	12330	11540	11725
9		12391	11598	11803	12468	11606	11896	12195	11301	11624	12459	11638	11885
10		12516	11695	11963	12593	11707	12076	12311	11397	11806	12585	11738	12055
11		12639	11795	12133	12715	11810	12262	12426	11495	11995	12709	11840	12232
12		12760	11896	12308	12835	11914	12455	12541	11596	12189	12831	11943	12415
13		12879	11998	12490	12954	12020	12652	12655	11700	12389	12951	12047	12604
14		12998	12102	12676	13072	12126	12852	12769	11804	12593	13069	12152	12797
15		13116	12206	12867	13188	12234	13057	12882	11911	12800	13187	12259	12994
16		13233	12312	13061	13304	12342	13264	12995	12018	13010	13304	12365	13194
17		13349	12418	13259	13419	12450	13473	13107	12126	13222	13421	12473	13397
18		13465	12524	13460	13533	12559	13684	13220	12234	13435	13536	12581	13602
19		13580	12632	13663	13647	12669	13896	13332	12344	13650	13651	12690	13810
20		13695	12740	13868	13761	12778	14110	13444	12453	13865	13766	12799	14019
CHANGE/PERIOD		123	97	159	125	99	174	117	92	171	124	99	167

TABLE 35. GENETIC LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, HIGH-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		11508	11008	11008	11513	11013	11013	11343	10843	10843	11531	11031	11031
2		11603	11103	11103	11608	11108	11108	11438	10938	10938	11625	11125	11125
3		11721	11177	11177	11746	11163	11163	11548	10966	10966	11766	11184	11184
4		11842	11250	11259	11881	11227	11245	11662	10990	11008	11890	11261	11279
5		11964	11325	11355	12012	11299	11350	11778	11024	11080	12015	11340	11386
6		12086	11404	11463	12140	11377	11475	11889	11096	11206	12139	11422	11506
7		12208	11485	11584	12265	11461	11616	12001	11167	11341	12263	11507	11638
8		12329	11569	11717	12387	11550	11771	12113	11244	11491	12386	11595	11781
9		12449	11657	11861	12508	11643	11937	12225	11330	11657	12508	11686	11935
10		12568	11748	12016	12627	11739	12112	12337	11421	11834	12628	11780	12099
11		12686	11842	12180	12745	11837	12295	12449	11516	12019	12747	11876	12272
12		12802	11939	12351	12862	11938	12484	12560	11614	12211	12865	11975	12452
13		12918	12037	12529	12977	12041	12679	12672	11715	12409	12981	12076	12637
14		13034	12137	12712	13092	12145	12878	12783	11818	12612	13097	12179	12827
15		13148	12239	12899	13207	12250	13081	12895	11923	12817	13212	12282	13022
16		13263	12341	13091	13321	12357	13286	13007	12029	13026	13327	12387	13220
17		13377	12445	13287	13434	12464	13495	13118	12136	13237	13441	12492	13421
18		13491	12550	13485	13547	12572	13705	13229	12244	13450	13555	12599	13625
19		13604	12656	13687	13660	12681	13917	13341	12352	13664	13668	12706	13832
20		13717	12762	13891	13773	12790	14130	13452	12461	13879	13781	12814	14040
CHANGE/PERIOD		117	92	154	119	94	169	111	86	166	119	94	162

TABLE 36. GENETIC LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, LOW-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		11241	10741	10741	11265	10765	10765	11094	10594	10594	11269	10769	10769
2		11336	10836	10836	11360	10860	10860	11189	10689	10689	11364	10864	10864
3		11472	10927	10927	11527	10952	10952	11331	10756	10756	11532	10957	10957
4		11612	11020	11029	11691	11047	11063	11479	10823	10839	11675	11053	11070
5		11752	11114	11144	11846	11145	11192	11631	10892	10943	11818	11151	11194
6		11892	11210	11270	11995	11245	11336	11762	10978	11080	11960	11251	11330
7		12030	11307	11407	12138	11346	11492	11890	11068	11232	12100	11351	11476
8		12166	11407	11554	12275	11450	11659	12018	11161	11395	12238	11454	11632
9		12300	11507	11712	12409	11555	11834	12142	11257	11568	12373	11557	11798
10		12431	11610	11878	12539	11660	12017	12263	11356	11752	12505	11662	11971
11		12557	11713	12051	12665	11767	12206	12382	11458	11942	12633	11767	12151
12		12682	11818	12231	12789	11875	12400	12500	11562	12137	12758	11874	12337
13		12805	11923	12415	12911	11983	12598	12617	11667	12338	12881	11981	12528
14		12926	12030	12604	13032	12091	12800	12733	11773	12542	13003	12089	12723
15		13046	12137	12797	13151	12200	13005	12848	11880	12749	13123	12197	12921
16		13166	12244	12994	13268	12310	13213	12962	11988	12959	13242	12306	13122
17		13284	12352	13193	13385	12420	13422	13076	12097	13171	13360	12415	13326
18		13401	12460	13396	13501	12530	13633	13189	12206	13384	13477	12524	13533
19		13518	12569	13600	13616	12640	13846	13302	12316	13598	13594	12634	13741
20		13633	12678	13807	13730	12751	14060	13414	12426	13814	13709	12744	13951
CHANGE/PERIOD		127	102	164	130	105	178	122	97	175	129	104	171

TABLE 37. GENETIC LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, MEDIUM-PRODUCTION LEVEL

PERIOD	COW SEL / SIRE SEL	1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1		11365	10865	10865	11385	10885	10885	11217	10717	10717	11396	10896	10896
2		11460	10960	10960	11480	10980	10980	11312	10812	10812	11491	10991	10991
3		11585	11041	11041	11632	11055	11055	11438	10861	10861	11644	11067	11067
4		11715	11123	11132	11780	11134	11150	11569	10908	10925	11777	11153	11170
5		11845	11207	11237	11923	11218	11267	11703	10958	11009	11910	11241	11285
6		11975	11293	11353	12061	11307	11400	11823	11036	11141	12043	11332	11412
7		12104	11382	11481	12194	11400	11548	11943	11117	11284	12175	11424	11550
8		12232	11473	11620	12324	11495	11708	12063	11202	11440	12305	11519	11699
9		12359	11566	11770	12451	11593	11877	12181	11292	11609	12433	11615	11859
10		12483	11662	11930	12575	11694	12055	12297	11387	11788	12559	11714	12027
11		12605	11761	12098	12697	11796	12241	12412	11485	11976	12682	11815	12202
12		12725	11861	12273	12817	11900	12432	12527	11585	12169	12803	11918	12385
13		12844	11962	12454	12936	12005	12627	12641	11688	12368	12923	12022	12572
14		12962	12065	12640	13054	12111	12827	12755	11793	12571	13042	12126	12765
15		13079	12169	12830	13170	12218	13030	12868	11898	12777	13159	12232	12961
16		13196	12274	13024	13286	12326	13236	12980	12005	12986	13276	12339	13160
17		13311	12380	13221	13401	12434	13445	13093	12113	13197	13392	12446	13362
18		13427	12486	13421	13515	12543	13655	13205	12221	13410	13507	12554	13567
19		13542	12593	13624	13629	12652	13867	13317	12330	13624	13622	12662	13774
20		13656	12701	13829	13743	12762	14080	13429	12440	13839	13737	12771	13983
CHANGE/PERIOD		122	96	158	124	99	173	117	91	170	124	99	166

TABLE 38. GENETIC LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, HIGH-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		11495	10995	10995	11505	11005	11005	11339	10839	10839	11522	11022	11022
2		11590	11090	11090	11600	11100	11100	11434	10934	10934	11617	11117	11117
3		11707	11162	11162	11735	11156	11156	11543	10963	10963	11755	11176	11176
4		11826	11234	11244	11868	11219	11236	11655	10990	11008	11878	11252	11270
5		11947	11308	11338	11998	11290	11340	11771	11020	11073	12002	11330	11375
6		12068	11385	11445	12125	11367	11462	11881	11091	11199	12125	11412	11493
7		12188	11466	11565	12249	11451	11602	11993	11163	11334	12249	11496	11624
8		12309	11549	11697	12371	11539	11754	12105	11239	11482	12371	11583	11766
9		12428	11636	11840	12491	11631	11919	12217	11324	11646	12493	11673	11919
10		12547	11726	11994	12610	11726	12092	12328	11415	11822	12613	11766	12081
11		12664	11819	12157	12727	11824	12274	12440	11509	12007	12731	11862	12253
12		12779	11916	12328	12844	11924	12462	12551	11607	12198	12848	11961	12432
13		12895	12014	12505	12960	12026	12655	12663	11707	12395	12964	12061	12616
14		13010	12113	12688	13074	12130	12853	12774	11810	12596	13080	12163	12806
15		13124	12214	12875	13189	12235	13055	12886	11915	12802	13195	12267	13000
16		13238	12317	13067	13303	12341	13259	12997	12020	13010	13309	12371	13197
17		13352	12421	13262	13416	12448	13467	13109	12127	13220	13424	12476	13398
18		13466	12525	13460	13529	12556	13676	13220	12235	13433	13537	12583	13601
19		13579	12631	13662	13642	12664	13887	13331	12343	13647	13651	12690	13807
20		13692	12737	13865	13755	12773	14100	13443	12452	13862	13764	12797	14015
CHANGE/PERIOD		116	91	153	119	93	168	111	86	165	118	93	161

TABLE 39. DHI LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, LOW-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		11302	10764	10764	11970	11436	11436	10836	10313	10313	11768	11221	11221
2		11404	10866	10866	12072	11537	11537	10935	10412	10412	11871	11325	11325
3		11532	10966	10966	12224	11637	11637	11070	10492	10492	12022	11429	11429
4		11683	11066	11072	12406	11739	11750	11235	10557	10569	12182	11534	11544
5		11835	11168	11191	12576	11843	11883	11400	10628	10673	12340	11641	11674
6		11989	11272	11323	12740	11950	12033	11536	10719	10819	12501	11750	11816
7		12141	11377	11467	12895	12059	12198	11671	10813	10978	12659	11861	11971
8		12291	11485	11624	13045	12169	12374	11807	10910	11147	12815	11973	12138
9		12437	11594	11791	13189	12281	12560	11938	11010	11329	12966	12087	12315
10		12580	11704	11968	13330	12394	12754	12065	11115	11521	13113	12202	12503
11		12717	11816	12153	13466	12509	12956	12190	11222	11721	13255	12317	12698
12		12852	11929	12345	13600	12624	13163	12314	11330	11926	13393	12434	12899
13		12985	12043	12543	13731	12739	13374	12436	11440	12136	13529	12552	13107
14		13117	12157	12745	13860	12855	13590	12557	11552	12350	13663	12670	13318
15		13247	12272	12952	13987	12972	13809	12677	11664	12568	13796	12788	13534
16		13376	12388	13163	14113	13089	14031	12797	11777	12787	13927	12907	13753
17		13504	12505	13377	14238	13207	14255	12916	11891	13009	14056	13026	13975
18		13631	12621	13594	14362	13324	14480	13034	12005	13233	14185	13146	14200
19		13757	12739	13814	14485	13442	14708	13152	12120	13458	14313	13266	14427
20		13882	12856	14036	14608	13560	14936	13270	12235	13683	14440	13386	14656
CHANGE/PERIOD		138	110	175	140	112	189	128	101	183	143	114	184

TABLE 40. DHI LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, MEDIUM-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		13576	12978	12978	14308	13714	13714	13019	12438	12438	14118	13510	13510
2		13689	13091	13091	14421	13827	13827	13129	12548	12548	14233	13625	13625
3		13825	13197	13197	14578	13925	13925	13266	12622	12622	14390	13729	13729
4		13981	13296	13303	14761	14017	14030	13426	12667	12680	14556	13833	13845
5		14139	13398	13423	14935	14116	14162	13585	12722	12775	14720	13940	13977
6		14298	13501	13558	15102	14221	14315	13724	12813	12927	14886	14049	14123
7		14457	13608	13708	15264	14330	14487	13864	12908	13093	15050	14161	14284
8		14613	13717	13872	15420	14443	14674	14005	13005	13272	15213	14275	14460
9		14767	13830	14049	15572	14560	14874	14143	13109	13468	15372	14392	14649
10		14918	13945	14238	15721	14679	15084	14278	13220	13677	15528	14512	14850
11		15065	14063	14438	15867	14800	15303	14413	13334	13895	15679	14635	15061
12		15210	14184	14646	16011	14923	15529	14546	13451	14119	15828	14760	15281
13		15353	14306	14861	16153	15048	15761	14679	13571	14351	15975	14886	15507
14		15495	14429	15082	16293	15174	15998	14811	13692	14587	16120	15013	15739
15		15637	14553	15309	16432	15301	16240	14942	13815	14827	16264	15142	15976
16		15777	14679	15540	16569	15429	16484	15074	13939	15070	16407	15271	16217
17		15916	14806	15775	16706	15558	16732	15204	14065	15316	16549	15402	16462
18		16055	14933	16014	16842	15688	16982	15335	14191	15563	16690	15533	16710
19		16193	15061	16256	16978	15817	17233	15465	14318	15812	16830	15665	16961
20		16330	15190	16501	17113	15948	17487	15595	14445	16063	16969	15797	17215
CHANGE/PERIOD		147	116	188	149	118	204	136	106	197	152	120	199

TABLE 41. DHI LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, HIGH-PRODUCTION LEVEL

PERIOD	COW SEL 1 / SIRE SEL 1	COW SEL 1 / SIRE SEL 2	COW SEL 1 / SIRE SEL 3	COW SEL 2 / SIRE SEL 1	COW SEL 2 / SIRE SEL 2	COW SEL 2 / SIRE SEL 3	COW SEL 3 / SIRE SEL 1	COW SEL 3 / SIRE SEL 2	COW SEL 3 / SIRE SEL 3	COW SEL 4 / SIRE SEL 1	COW SEL 4 / SIRE SEL 2	COW SEL 4 / SIRE SEL 3
1	15814	15157	15157	16629	15976	15976	15182	14542	14542	16429	15759	15759
2	15939	15281	15281	16753	16100	16100	15303	14663	14663	16556	15886	15886
3	16081	15390	15390	16912	16192	16192	15437	14726	14726	16716	15987	15987
4	16239	15486	15493	17092	16269	16284	15585	14745	14760	16884	16086	16099
5	16399	15583	15612	17265	16360	16412	15734	14783	14842	17050	16190	16231
6	16560	15684	15746	17434	16459	16566	15875	14870	14997	17218	16295	16378
7	16722	15788	15898	17599	16567	16743	16018	14962	15169	17387	16405	16542
8	16883	15897	16067	17760	16681	16939	16162	15058	15356	17554	16519	16724
9	17042	16010	16252	17919	16800	17151	16306	15166	15564	17719	16638	16923
10	17199	16129	16452	18075	16924	17376	16448	15282	15789	17881	16761	17136
11	17354	16252	16664	18229	17052	17612	16591	15402	16024	18041	16889	17362
12	17507	16379	16887	18382	17183	17857	16734	15527	16268	18199	17020	17598
13	17659	16507	17119	18534	17316	18109	16877	15656	16520	18355	17154	17842
14	17811	16638	17357	18685	17451	18367	17020	15787	16778	18510	17290	18094
15	17963	16771	17602	18834	17588	18630	17162	15920	17040	18665	17428	18351
16	18113	16906	17853	18983	17727	18898	17305	16055	17306	18819	17568	18614
17	18264	17042	18108	19132	17867	19168	17447	16192	17576	18972	17708	18881
18	18413	17180	18369	19280	18008	19442	17590	16330	17847	19125	17850	19152
19	18563	17318	18633	19427	18149	19718	17732	16469	18121	19277	17993	19427
20	18712	17458	18900	19575	18292	19996	17875	16608	18396	19429	18137	19705
CHANGE/PERIOD	154	120	199	156	122	217	142	109	210	159	124	211

TABLE 42. DHI LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, LOW-PRODUCTION LEVEL

PERIOD	COW SEL / SIRE SEL	1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1		11200	10667	10667	11839	11309	11309	10766	10246	10246	11647	11105	11105
2		11302	10768	10768	11940	11410	11410	10864	10344	10344	11749	11208	11208
3		11428	10867	10867	12088	11509	11509	10995	10424	10424	11895	11309	11309
4		11576	10965	10971	12265	11608	11619	11155	10489	10500	12052	11412	11422
5		11727	11065	11088	12433	11711	11749	11315	10558	10601	12207	11517	11548
6		11878	11166	11217	12594	11816	11896	11453	10646	10740	12365	11623	11687
7		12028	11270	11359	12747	11923	12057	11586	10739	10896	12520	11732	11838
8		12175	11375	11513	12895	12032	12230	11719	10835	11062	12673	11842	12002
9		12320	11482	11678	13038	12143	12413	11849	10934	11241	12822	11953	12177
10		12460	11591	11853	13177	12254	12604	11975	11037	11430	12966	12066	12361
11		12596	11701	12036	13313	12367	12802	12100	11142	11626	13106	12180	12553
12		12729	11813	12226	13445	12481	13006	12223	11249	11829	13243	12295	12751
13		12860	11925	12421	13575	12595	13215	12344	11358	12036	13377	12410	12955
14		12991	12038	12622	13704	12710	13428	12465	11468	12248	13509	12527	13164
15		13120	12152	12827	13830	12826	13644	12584	11580	12463	13640	12644	13377
16		13247	12267	13036	13955	12942	13863	12703	11692	12680	13770	12761	13594
17		13374	12382	13248	14079	13058	14084	12821	11805	12900	13898	12879	13813
18		13499	12498	13463	14202	13175	14308	12939	11918	13121	14026	12998	14035
19		13624	12614	13681	14324	13292	14533	13057	12032	13344	14152	13116	14260
20		13748	12730	13901	14446	13409	14759	13174	12146	13568	14277	13235	14486
CHANGE/PERIOD		136	108	173	138	111	186	127	100	180	140	112	181

TABLE 43. DHI LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, MEDIUM-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		13447	12854	12854	14181	13592	13592	12920	12343	12343	13974	13371	13371
2		13560	12967	12967	14292	13703	13703	13029	12452	12452	14088	13486	13486
3		13694	13070	13070	14445	13800	13800	13162	12526	12526	14241	13588	13588
4		13846	13167	13173	14624	13891	13903	13318	12572	12585	14402	13689	13700
5		14000	13265	13290	14794	13988	14032	13474	12626	12676	14563	13793	13829
6		14156	13365	13422	14959	14091	14182	13613	12713	12822	14726	13900	13971
7		14311	13469	13568	15118	14198	14350	13751	12807	12986	14887	14009	14129
8		14465	13575	13729	15273	14310	14533	13890	12903	13162	15047	14120	14301
9		14616	13685	13903	15424	14424	14729	14027	13006	13353	15204	14235	14486
10		14764	13799	14090	15571	14542	14936	14161	13115	13559	15357	14353	14684
11		14908	13915	14287	15716	14662	15151	14294	13228	13774	15506	14474	14892
12		15051	14033	14492	15858	14783	15374	14426	13343	13995	15653	14597	15108
13		15193	14153	14705	15998	14907	15603	14558	13461	14224	15797	14721	15331
14		15333	14275	14923	16137	15031	15837	14689	13581	14457	15941	14847	15560
15		15473	14398	15147	16275	15157	16075	14820	13703	14694	16083	14974	15793
16		15611	14522	15376	16412	15284	16317	14950	13826	14935	16224	15101	16032
17		15749	14647	15609	16548	15411	16561	15080	13950	15178	16365	15230	16273
18		15886	14773	15846	16683	15539	16808	15209	14075	15423	16504	15360	16519
19		16022	14900	16085	16817	15668	17057	15339	14201	15670	16643	15490	16767
20		16158	15028	16328	16951	15797	17308	15468	14327	15918	16781	15620	17017
CHANGE/PERIOD		144	114	185	147	116	201	135	105	194	149	118	195

TABLE 44. DHI LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, HIGH-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		15675	15023	15023	16475	15827	15827	15046	14412	14412	16277	15614	15614
2		15799	15146	15146	16598	15950	15950	15166	14532	14532	16403	15740	15740
3		15939	15253	15253	16753	16041	16041	15299	14597	14597	16560	15839	15839
4		16094	15347	15354	16929	16118	16132	15443	14618	14632	16724	15936	15949
5		16251	15442	15470	17098	16207	16256	15590	14650	14707	16887	16038	16078
6		16410	15540	15602	17264	16304	16406	15730	14737	14860	17053	16142	16222
7		16569	15642	15751	17426	16409	16579	15871	14828	15029	17219	16249	16383
8		16727	15749	15917	17585	16521	16771	16013	14923	15213	17383	16361	16562
9		16884	15860	16100	17742	16639	16979	16155	15028	15417	17546	16478	16757
10		17038	15977	16297	17897	16761	17200	16296	15143	15639	17706	16600	16966
11		17191	16098	16507	18050	16887	17432	16438	15262	15871	17864	16726	17189
12		17343	16223	16728	18201	17016	17673	16579	15385	16112	18020	16855	17422
13		17493	16350	16957	18351	17147	17922	16720	15512	16360	18174	16988	17663
14		17643	16480	17193	18501	17281	18176	16862	15641	16615	18328	17122	17911
15		17793	16611	17435	18649	17417	18436	17003	15773	16874	18481	17258	18165
16		17942	16744	17684	18797	17554	18700	17144	15907	17138	18633	17396	18425
17		18091	16879	17937	18944	17692	18968	17286	16042	17404	18785	17535	18689
18		18239	17015	18195	19091	17831	19238	17427	16179	17673	18936	17675	18957
19		18387	17152	18456	19237	17971	19511	17568	16316	17944	19087	17816	19228
20		18535	17291	18721	19383	18112	19787	17709	16454	18216	19237	17959	19503
CHANGE/PERIOD		152	118	197	154	120	214	141	108	207	157	123	208

TABLE 45. 305-DAY ME LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, LOW-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		12104	11528	11528	12740	12164	12164	11932	11356	11356	12238	11662	11662
2		12214	11638	11638	12849	12273	12273	12041	11465	11465	12347	11771	11771
3		12354	11745	11745	13019	12381	12381	12188	11553	11553	12524	11880	11880
4		12519	11852	11860	13218	12491	12504	12364	11628	11641	12699	11992	12007
5		12682	11962	11989	13401	12603	12650	12549	11704	11752	12864	12106	12149
6		12845	12073	12131	13576	12719	12813	12702	11803	11909	13030	12222	12304
7		13006	12186	12287	13742	12836	12992	12849	11907	12084	13193	12339	12472
8		13165	12301	12455	13903	12956	13183	12999	12013	12269	13354	12457	12651
9		13321	12418	12634	14058	13076	13385	13144	12124	12469	13512	12577	12841
10		13473	12536	12824	14209	13199	13595	13284	12239	12680	13665	12699	13040
11		13621	12656	13022	14356	13322	13813	13422	12356	12900	13815	12821	13247
12		13766	12777	13228	14500	13446	14036	13558	12476	13125	13960	12944	13461
13		13908	12899	13439	14641	13570	14265	13693	12597	13356	14103	13068	13681
14		14049	13021	13656	14780	13696	14498	13827	12719	13592	14244	13193	13905
15		14188	13145	13878	14917	13822	14734	13959	12843	13831	14383	13318	14133
16		14327	13269	14104	15053	13948	14973	14091	12968	14073	14521	13443	14365
17		14463	13393	14333	15187	14074	15215	14222	13093	14318	14657	13569	14600
18		14599	13518	14566	15321	14201	15458	14352	13219	14564	14792	13695	14838
19		14734	13644	14801	15453	14328	15703	14482	13345	14811	14927	13822	15077
20		14868	13769	15038	15585	14456	15950	14612	13472	15060	15060	13949	15319
CHANGE/PERIOD		148	118	188	151	121	204	142	112	201	150	120	196

TABLE 46. 305-DAY ME LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, MEDIUM-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		14540	13900	13900	15227	14587	14587	14336	13696	13696	14661	14021	14021
2		14661	14021	14021	15349	14709	14709	14457	13817	13817	14782	14142	14142
3		14810	14133	14133	15524	14813	14813	14606	13899	13899	14964	14247	14247
4		14980	14239	14247	15724	14911	14927	14778	13955	13969	15144	14356	14373
5		15148	14348	14378	15910	15019	15072	14955	14012	14067	15315	14470	14519
6		15317	14460	14524	16089	15133	15240	15111	14110	14230	15487	14586	14680
7		15485	14574	14686	16262	15251	15427	15265	14214	14413	15657	14706	14856
8		15652	14692	14863	16430	15373	15630	15420	14321	14609	15826	14827	15045
9		15816	14812	15053	16594	15499	15847	15572	14435	14823	15992	14952	15248
10		15977	14936	15256	16754	15628	16074	15721	14557	15053	16155	15079	15462
11		16135	15062	15469	16911	15759	16311	15869	14683	15292	16314	15208	15686
12		16290	15191	15692	17066	15892	16555	16016	14811	15540	16471	15340	15919
13		16444	15322	15923	17219	16027	16806	16163	14943	15794	16625	15473	16159
14		16596	15454	16160	17369	16163	17062	16308	15076	16054	16777	15608	16405
15		16747	15587	16402	17519	16300	17322	16453	15212	16318	16928	15743	16655
16		16897	15722	16650	17667	16438	17586	16598	15349	16586	17078	15880	16910
17		17046	15857	16902	17815	16577	17853	16742	15487	16856	17227	16017	17169
18		17195	15994	17158	17961	16716	18123	16886	15625	17129	17376	16155	17431
19		17342	16131	17417	18107	16856	18394	17029	15765	17403	17523	16294	17696
20		17489	16269	17679	18252	16996	18667	17172	15905	17679	17670	16434	17964
CHANGE/PERIOD		157	124	202	160	127	221	150	117	217	160	127	212

TABLE 47. 305-DAY ME LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 40-COW HERD, HIGH-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		16937	16233	16233	17691	16987	16987	16707	16004	16003	17038	16334	16334
2		17070	16366	16366	17824	17120	17120	16841	16137	16137	17171	16467	16467
3		17225	16480	16480	18000	17215	17215	16989	16209	16209	17353	16562	16562
4		17396	16581	16590	18196	17298	17315	17149	16237	16253	17534	16664	16683
5		17567	16686	16719	18381	17397	17456	17314	16273	16335	17708	16776	16831
6		17739	16795	16867	18562	17505	17626	17470	16366	16501	17884	16890	16994
7		17911	16908	17032	18739	17622	17819	17627	16468	16690	18058	17008	17176
8		18082	17026	17214	18912	17745	18032	17786	16574	16894	18232	17131	17374
9		18252	17148	17413	19083	17874	18262	17944	16691	17122	18404	17257	17587
10		18420	17274	17626	19251	18008	18506	18101	16818	17369	18575	17388	17814
11		18586	17406	17854	19418	18146	18761	18258	16951	17627	18742	17523	18054
12		18750	17541	18092	19582	18288	19025	18415	17088	17895	18908	17662	18304
13		18913	17679	18340	19746	18431	19298	18573	17229	18172	19072	17804	18564
14		19076	17820	18596	19908	18577	19576	18730	17373	18455	19236	17947	18830
15		19238	17962	18858	20069	18725	19861	18887	17520	18744	19398	18093	19102
16		19399	18106	19127	20230	18875	20149	19044	17669	19037	19560	18240	19380
17		19560	18252	19401	20389	19026	20441	19201	17819	19333	19721	18388	19663
18		19720	18399	19679	20549	19177	20736	19358	17971	19632	19881	18538	19949
19		19880	18548	19962	20708	19330	21034	19515	18124	19934	20041	18688	20238
20		20040	18697	20248	20866	19483	21334	19672	18277	20236	20200	18840	20531
CHANGE/PERIOD		165	128	214	168	132	235	157	120	231	167	132	225

TABLE 48. 305-DAY ME LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, LOW-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		12089	11513	11513	12722	12146	12146	11923	11347	11347	12249	11673	11673
2		12198	11622	11622	12831	12255	12255	12032	11456	11456	12358	11782	11782
3		12338	11729	11729	12998	12362	12362	12176	11544	11544	12530	11890	11890
4		12501	11835	11842	13193	12471	12484	12348	11619	11631	12703	12000	12014
5		12663	11942	11969	13374	12583	12627	12527	11695	11741	12866	12112	12154
6		12824	12052	12111	13548	12697	12789	12682	11790	11892	13031	12226	12306
7		12984	12164	12265	13714	12814	12965	12829	11894	12064	13193	12342	12472
8		13142	12278	12432	13874	12932	13154	12977	11999	12248	13353	12459	12649
9		13297	12394	12610	14029	13053	13354	13121	12109	12444	13509	12578	12837
10		13449	12511	12799	14179	13174	13562	13261	12223	12653	13662	12698	13034
11		13596	12630	12996	14326	13297	13778	13399	12339	12870	13811	12820	13240
12		13740	12750	13201	14470	13421	14000	13536	12458	13094	13956	12942	13453
13		13881	12872	13413	14611	13545	14228	13670	12579	13324	14098	13066	13671
14		14022	12994	13629	14750	13670	14459	13804	12701	13558	14238	13190	13894
15		14161	13117	13850	14888	13796	14695	13936	12824	13796	14377	13314	14122
16		14298	13240	14076	15023	13922	14933	14068	12948	14037	14515	13439	14353
17		14435	13365	14305	15158	14048	15173	14199	13073	14280	14651	13565	14587
18		14570	13489	14537	15292	14175	15416	14330	13199	14525	14786	13691	14824
19		14705	13615	14772	15424	14302	15661	14460	13325	14772	14921	13817	15063
20		14838	13740	15009	15556	14429	15907	14590	13451	15020	15054	13944	15304
CHANGE/PERIOD		147	117	187	150	120	203	141	111	199	149	120	195

TABLE 49. 305-DAY ME LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, MEDIUM-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		14514	13874	13874	15236	14596	14596	14328	13688	13688	14676	14036	14036
2		14635	13995	13995	15357	14717	14717	14449	13809	13809	14797	14157	14157
3		14782	14105	14105	15529	14821	14821	14596	13892	13892	14974	14261	14261
4		14949	14208	14217	15725	14919	14933	14765	13949	13963	15151	14367	14383
5		15116	14315	14345	15909	15025	15076	14940	14005	14058	15321	14480	14527
6		15282	14425	14490	16087	15138	15242	15095	14100	14216	15491	14595	14685
7		15448	14537	14649	16259	15255	15426	15248	14204	14397	15660	14712	14859
8		15613	14653	14824	16427	15376	15627	15402	14310	14592	15828	14832	15046
9		15775	14771	15012	16590	15501	15841	15554	14424	14803	15992	14955	15246
10		15935	14893	15213	16750	15629	16066	15703	14544	15031	16155	15081	15458
11		16091	15019	15426	16907	15760	16301	15851	14669	15268	16313	15210	15681
12		16246	15146	15648	17061	15892	16544	15998	14797	15514	16469	15341	15913
13		16398	15276	15877	17214	16026	16793	16144	14928	15766	16622	15473	16151
14		16549	15407	16113	17365	16162	17048	16290	15061	16025	16774	15607	16396
15		16700	15540	16355	17514	16298	17307	16434	15196	16288	16925	15742	16645
16		16849	15674	16602	17662	16436	17570	16579	15332	16554	17075	15878	16899
17		16998	15809	16853	17810	16574	17836	16723	15470	16824	17224	16015	17157
18		17146	15945	17109	17956	16714	18104	16867	15608	17096	17371	16153	17419
19		17293	16082	17367	18102	16853	18375	17010	15748	17370	17519	16291	17683
20		17439	16219	17629	18248	16994	18648	17154	15888	17645	17665	16431	17950
CHANGE/PERIOD		156	123	200	159	126	219	149	116	215	159	126	210

TABLE 50. 305-DAY ME LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM: 120-COW HERD, HIGH-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		16918	16214	16214	17688	16984	16984	16701	15997	15997	17066	16362	16362
2		17051	16347	16347	17822	17118	17118	16835	16131	16131	17200	16496	16496
3		17205	16460	16460	17995	17214	17214	16981	16204	16204	17379	16592	16592
4		17374	16559	16568	18187	17296	17312	17140	16237	16253	17558	16692	16710
5		17543	16663	16696	18370	17393	17451	17304	16267	16326	17730	16803	16856
6		17714	16770	16842	18550	17500	17617	17459	16359	16491	17905	16916	17017
7		17884	16882	17005	18726	17616	17808	17616	16462	16679	18079	17033	17197
8		18054	16998	17186	18898	17738	18018	17773	16567	16882	18251	17154	17392
9		18222	17118	17383	19068	17866	18246	17931	16682	17107	18423	17280	17603
10		18390	17244	17596	19236	17999	18487	18088	16809	17352	18593	17410	17829
11		18555	17374	17822	19402	18136	18740	18245	16941	17609	18760	17544	18068
12		18718	17509	18060	19566	18277	19002	18402	17077	17876	18925	17682	18317
13		18881	17646	18308	19729	18420	19273	18559	17218	18151	19089	17823	18575
14		19043	17786	18563	19891	18565	19550	18716	17362	18434	19252	17966	18840
15		19204	17928	18824	20053	18713	19832	18873	17508	18721	19414	18111	19111
16		19365	18072	19093	20213	18862	20120	19030	17657	19014	19576	18258	19388
17		19525	18217	19366	20373	19012	20411	19187	17807	19309	19737	18406	19670
18		19685	18364	19644	20532	19163	20705	19344	17958	19608	19897	18555	19955
19		19845	18512	19927	20691	19316	21002	19501	18111	19908	20057	18706	20244
20		20004	18662	20213	20850	19469	21301	19658	18264	20211	20216	18857	20536
CHANGE/PERIOD		164	127	213	167	131	233	156	120	229	167	131	224

TABLE 51. GENOTYPIC AND PHENOTYPIC AVERAGES[a] FOR EACH HERD SIZE AND PRODUCTION LEVEL

HS EI RZ DE	L PE RV OE DL	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
		SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
		GENETIC LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM												
40	LOW		1483	701	1100	1568	740	1235	1308	461	996	1555	753	1197
40	MEDIUM		1555	773	1172	1618	788	1288	1351	502	1042	1618	814	1261
40	HIGH		1615	833	1232	1665	832	1337	1392	541	1084	1671	865	1315
120	LOW		1462	680	1079	1554	729	1217	1291	447	974	1530	730	1169
120	MEDIUM		1523	741	1140	1602	775	1268	1338	492	1025	1593	792	1234
120	HIGH		1595	812	1212	1649	820	1317	1384	535	1073	1656	852	1298
		DHI LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM												
40	LOW		1613	779	1187	2344	1468	1973	1091	211	756	2139	1275	1725
40	MEDIUM		3964	3038	3491	4752	3775	4342	3325	2343	2955	4568	3606	4109
40	HIGH		6261	5242	5742	7124	6048	6676	5519	4437	5114	6939	5878	6434
120	LOW		1494	667	1072	2194	1328	1821	1004	132	665	1994	1140	1582
120	MEDIUM		3812	2893	3343	4603	3638	4192	3208	2237	2836	4399	3447	3941
120	HIGH		6102	5091	5586	6948	5884	6499	5367	4296	4962	6765	5716	6263
		305 DAY ME LEVELS (PER COW) FOR THE 20 PERIODS FOR EACH SELECTION SYSTEM												
40	LOW		2510	1616	2057	3225	2278	2829	2313	1344	1940	2694	1776	2270
40	MEDIUM		5028	4035	4525	5787	4732	5350	4772	3693	4361	5198	4176	4729
40	HIGH		7488	6395	6934	8305	7141	7827	7179	5989	6728	7635	6510	7121
120	LOW		2486	1592	2034	3198	2254	2797	2293	1328	1914	2693	1777	2266
120	MEDIUM		4987	3994	4485	5785	4734	5343	4756	3681	4339	5200	4180	4727
120	HIGH		7459	6366	6905	8292	7132	7809	7167	5980	6713	7655	6532	7137

[a]ALL LEVELS EXPRESSED AS DEVIATIONS FROM 11,000 POUNDS

TABLE 52. AVERAGE PROFIT PER PERIOD PER COW: 40-COW HERD, LOW-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		110	78	85	124	92	102	86	51	64	112	80	88
1	1	2		88	56	63	85	52	62	47	11	24	72	40	48
1	1	3		66	34	41	45	12	22	7	-28	-15	33	1	8
1	2	1		27	-1	4	40	10	18	5	-26	-15	28	0	5
1	2	2		5	-23	-17	0	-29	-21	-33	-66	-55	-11	-40	-34
1	2	3		-16	-45	-39	-39	-69	-60	-73	-106	-95	-50	-80	-74
1	3	1		-82	-107	-103	-73	-99	-93	-102	-130	-122	-83	-109	-105
1	3	2		-104	-129	-125	-112	-138	-132	-141	-170	-161	-123	-148	-144
1	3	3		-126	-151	-147	-152	-178	-172	-181	-210	-201	-163	-188	-184
2	1	1		177	141	150	196	159	172	151	111	127	183	146	156
2	1	2		156	119	129	157	119	132	112	71	87	143	106	116
2	1	3		134	97	107	117	79	92	72	32	47	103	67	77
2	2	1		95	61	69	111	77	88	70	33	47	99	65	73
2	2	2		73	40	47	72	37	48	31	-6	7	59	25	33
2	2	3		51	18	26	32	-2	8	-8	-45	-31	19	-14	-5
2	3	1		-14	-44	-38	-1	-32	-23	-37	-70	-59	-13	-43	-36
2	3	2		-36	-66	-60	-41	-71	-63	-76	-110	-98	-52	-82	-76
2	3	3		-58	-88	-82	-80	-111	-102	-116	-149	-138	-92	-122	-116
3	1	1		313	268	281	340	293	311	281	232	253	324	278	293
3	1	2		291	246	260	300	253	271	242	192	214	284	238	253
3	1	3		269	224	238	260	213	232	202	152	174	245	199	213
3	2	1		231	188	200	255	211	227	200	154	173	240	197	210
3	2	2		209	166	178	215	171	188	161	114	134	200	157	170
3	2	3		187	144	157	175	131	148	121	74	94	160	117	131
3	3	1		121	82	92	141	101	116	92	50	67	128	88	100
3	3	2		99	60	70	102	62	76	53	10	27	88	49	60
3	3	3		77	38	49	62	22	36	13	-29	-12	48	9	20
MEAN				86	51	60	86	50	62	43	5	20	73	38	47

TABLE 53. AVERAGE PROFIT PER PERIOD PER COW: 40-COW HERD, MEDIUM-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		204	171	179	220	183	195	188	152	166	209	173	182
1	1	2		182	149	157	179	143	154	147	111	125	168	132	141
1	1	3		161	127	135	138	102	113	106	70	84	127	91	100
1	2	1		114	83	90	127	94	104	100	67	79	116	84	92
1	2	2		92	62	68	86	53	63	59	26	38	75	43	51
1	2	3		70	40	47	45	12	22	18	-14	-2	34	2	10
1	3	1		-6	-32	-27	3	-25	-18	-17	-45	-36	-6	-34	-29
1	3	2		-27	-54	-49	-37	-66	-59	-58	-86	-77	-47	-75	-70
1	3	3		-49	-76	-71	-78	-107	-100	-99	-127	-118	-88	-116	-111
2	1	1		285	246	257	304	263	278	265	224	241	292	251	264
2	1	2		263	224	235	264	222	237	224	183	200	251	210	223
2	1	3		241	202	213	223	181	196	183	142	159	210	169	182
2	2	1		194	159	168	211	173	186	177	139	154	200	162	173
2	2	2		173	137	146	170	132	145	136	98	113	159	121	132
2	2	3		151	115	124	130	91	104	95	57	72	118	80	91
2	3	1		74	43	50	87	53	64	59	25	38	77	43	52
2	3	2		52	21	28	46	12	23	18	-15	-2	36	2	11
2	3	3		30	0	6	5	-27	-17	-22	-56	-43	-4	-38	-29
3	1	1		446	397	413	474	422	443	419	367	391	460	408	426
3	1	2		424	375	391	433	381	402	378	326	350	419	367	385
3	1	3		402	353	369	392	340	361	337	285	309	378	326	344
3	2	1		355	310	324	381	332	351	331	282	304	367	319	335
3	2	2		333	288	302	340	291	310	290	241	263	326	278	294
3	2	3		312	266	280	299	250	269	249	200	222	285	237	253
3	3	1		235	193	206	257	212	229	213	169	188	244	200	214
3	3	2		213	172	184	216	171	188	172	128	147	203	159	173
3	3	3		191	150	162	175	130	147	131	87	106	162	118	132
MEAN				189	152	162	188	148	162	151	112	128	176	137	148

TABLE 54. AVERAGE PROFIT PER PERIOD PER COW: 40-COW HERD, HIGH-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL 1 / SIRE SEL 1	COW SEL 1 / SIRE SEL 2	COW SEL 1 / SIRE SEL 3	COW SEL 2 / SIRE SEL 1	COW SEL 2 / SIRE SEL 2	COW SEL 2 / SIRE SEL 3	COW SEL 3 / SIRE SEL 1	COW SEL 3 / SIRE SEL 2	COW SEL 3 / SIRE SEL 3	COW SEL 4 / SIRE SEL 1	COW SEL 4 / SIRE SEL 2	COW SEL 4 / SIRE SEL 3
1	1	1	293	256	266	309	271	283	287	250	265	298	260	270
1	1	2	271	234	244	266	229	241	245	207	223	256	218	228
1	1	3	249	212	222	224	186	199	202	165	180	213	176	186
1	2	1	195	161	170	207	173	184	191	157	170	197	163	171
1	2	2	173	139	148	165	131	141	149	115	128	155	121	129
1	2	3	151	118	126	123	89	99	106	73	86	113	79	87
1	3	1	64	35	41	72	43	50	63	34	44	63	34	40
1	3	2	42	13	19	30	1	8	21	-7	2	21	-7	-2
1	3	3	20	-8	-2	-11	-40	-33	-20	-49	-39	-20	-49	-44
2	1	1	386	343	356	406	362	378	376	332	351	394	351	364
2	1	2	364	321	334	364	320	336	333	290	309	352	309	322
2	1	3	342	300	312	321	278	294	291	248	267	310	266	279
2	2	1	288	249	260	305	265	279	280	240	257	294	254	265
2	2	2	266	227	238	262	223	236	238	198	215	251	212	223
2	2	3	244	205	216	220	180	194	195	156	172	209	169	181
2	3	1	157	122	131	169	135	145	152	117	131	160	125	133
2	3	2	135	100	109	127	92	103	110	75	89	117	83	91
2	3	3	113	79	87	85	50	61	67	33	46	75	40	49
3	1	1	571	518	536	601	546	568	553	498	525	587	532	551
3	1	2	550	496	514	559	503	526	511	456	482	545	490	509
3	1	3	528	474	492	516	461	484	469	414	440	503	448	467
3	2	1	473	423	440	499	448	469	457	406	430	487	435	452
3	2	2	451	401	418	457	406	426	415	364	388	444	393	410
3	2	3	429	379	396	415	364	384	373	322	346	402	351	368
3	3	1	342	297	311	364	318	335	330	283	304	352	306	321
3	3	2	320	275	289	322	276	293	287	241	262	310	264	278
3	3	3	298	253	267	280	233	251	245	199	220	268	222	236
MEAN			285	245	257	283	242	256	256	215	233	272	231	243

TABLE 55. AVERAGE PROFIT PER PERIOD PER COW: 120-COW HERD, LOW-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL / SIRE SEL: 1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1	1	1	205	173	180	220	187	197	183	147	160	208	176	184
1	1	2	183	151	158	182	149	159	145	109	122	170	138	146
1	1	3	162	129	137	144	112	121	107	72	84	133	100	108
1	2	1	123	94	99	135	105	114	102	69	80	124	95	101
1	2	2	101	72	77	97	68	76	64	31	42	86	57	63
1	2	3	79	50	56	59	30	38	26	-5	4	49	19	25
1	3	1	13	-12	-8	22	-3	2	-5	-34	-25	12	-12	-8
1	3	2	-8	-33	-30	-15	-41	-35	-43	-72	-63	-25	-50	-46
1	3	3	-30	-55	-51	-53	-78	-72	-81	-110	-101	-62	-88	-84
2	1	1	273	236	246	291	254	267	248	208	223	279	242	252
2	1	2	251	215	224	254	216	229	210	170	185	241	204	214
2	1	3	229	193	202	216	178	191	172	132	147	203	166	176
2	2	1	191	157	165	207	172	183	167	130	143	195	161	169
2	2	2	169	135	143	169	134	145	129	92	105	157	123	131
2	2	3	147	113	121	131	97	107	91	54	67	119	85	93
2	3	1	81	51	57	93	63	72	59	25	37	83	53	59
2	3	2	59	29	35	56	25	34	21	-11	0	45	15	21
2	3	3	37	7	13	18	-12	-3	-16	-49	-38	7	-22	-16
3	1	1	408	363	376	434	388	405	378	328	349	419	373	388
3	1	2	387	341	355	397	350	368	340	290	311	382	336	350
3	1	3	365	319	333	359	312	330	302	252	274	344	298	312
3	2	1	326	283	295	349	306	322	297	250	270	335	292	306
3	2	2	304	261	274	312	268	284	259	212	232	298	254	268
3	2	3	282	239	252	274	230	246	221	174	194	260	217	230
3	3	1	216	177	187	236	197	210	189	146	163	223	184	195
3	3	2	194	155	166	199	159	173	151	108	125	186	146	157
3	3	3	172	133	144	161	121	135	113	70	87	148	108	120
MEAN			182	147	155	183	147	159	141	103	117	171	135	144

TABLE 56. AVERAGE PROFIT PER PERIOD PER COW: 120-COW HERD, MEDIUM-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL 1	1	1	2	2	2	3	3	3	4	4	4
		SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1	299	265	273	316	280	292	280	244	258	304	269	278
1	1	2	277	243	252	277	241	252	241	205	219	265	230	239
1	1	3	255	221	230	238	202	213	202	166	180	226	191	200
1	2	1	209	178	185	223	190	200	192	159	171	212	180	187
1	2	2	187	156	163	184	151	161	152	120	132	173	141	148
1	2	3	165	134	141	145	112	122	113	81	93	134	102	109
1	3	1	88	62	67	99	71	78	74	46	55	89	61	66
1	3	2	66	40	45	60	32	39	35	7	16	50	22	27
1	3	3	44	18	23	21	-6	0	-4	-32	-22	11	-16	-11
2	1	1	379	340	351	401	359	374	357	316	333	388	347	359
2	1	2	357	318	329	362	320	335	318	277	294	348	308	320
2	1	3	335	297	307	323	281	296	279	238	255	309	269	281
2	2	1	289	253	263	308	270	282	268	231	246	295	258	268
2	2	2	267	231	241	269	230	243	229	192	207	256	219	229
2	2	3	245	209	219	230	191	204	190	153	168	217	180	190
2	3	1	168	137	144	184	150	160	151	117	130	172	140	147
2	3	2	147	115	122	145	111	121	112	78	91	133	100	108
2	3	3	125	93	101	106	72	82	72	39	52	94	61	69
3	1	1	539	491	507	570	518	538	511	459	483	554	504	521
3	1	2	518	469	485	531	479	499	472	420	444	515	465	482
3	1	3	496	447	463	492	440	460	433	381	405	476	425	442
3	2	1	449	404	418	477	428	447	422	374	396	462	415	430
3	2	2	427	382	396	438	389	408	383	335	357	423	376	391
3	2	3	405	360	374	399	350	369	344	296	318	384	336	352
3	3	1	329	288	300	353	309	325	305	261	280	339	296	309
3	3	2	307	266	278	314	269	286	265	222	241	300	257	270
3	3	3	285	244	256	275	230	247	226	183	202	261	218	231
MEAN			283	246	256	286	246	260	245	206	222	273	235	245

TABLE 57. AVERAGE PROFIT PER PERIOD PER COW: 120-COW HERD, HIGH-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL / SIRE SEL	1 1	1 2	1 3	2 1	2 2	2 3	3 1	3 2	3 3	4 1	4 2	4 3
1	1	1		388	351	361	405	367	380	380	343	358	394	357	367
1	1	2		366	329	339	364	327	340	340	302	317	354	317	327
1	1	3		345	307	318	324	286	300	299	262	277	313	276	287
1	2	1		290	256	265	303	269	280	284	250	263	294	260	269
1	2	2		268	235	243	263	229	240	244	210	223	253	220	228
1	2	3		246	213	221	223	189	200	203	170	183	213	179	188
1	3	1		159	130	136	168	139	148	156	128	137	160	131	137
1	3	2		137	108	115	128	99	107	116	87	97	119	91	97
1	3	3		115	87	93	88	59	67	76	47	57	79	50	56
2	1	1		481	438	451	502	458	475	469	425	444	490	447	461
2	1	2		459	416	429	461	418	435	428	385	404	450	407	420
2	1	3		437	395	407	421	378	394	388	345	364	410	367	380
2	2	1		383	344	355	401	361	375	373	333	350	390	351	362
2	2	2		361	322	333	360	321	335	332	293	309	349	310	322
2	2	3		339	300	311	320	280	295	292	253	269	309	270	281
2	3	1		252	217	226	266	231	242	245	211	224	256	222	231
2	3	2		230	196	204	225	191	202	205	170	184	216	181	190
2	3	3		208	174	182	185	150	162	164	130	143	175	141	150
3	1	1		666	613	631	696	641	665	646	591	617	683	629	648
3	1	2		644	591	609	656	601	624	606	551	577	642	588	608
3	1	3		622	569	587	616	561	584	565	510	536	602	548	567
3	2	1		568	518	534	595	544	565	550	499	523	582	532	549
3	2	2		546	496	513	555	503	525	510	459	482	542	491	509
3	2	3		524	474	491	514	463	484	469	418	442	502	451	468
3	3	1		437	392	406	460	414	432	422	376	397	448	403	418
3	3	2		415	370	384	420	374	392	382	336	357	408	362	377
3	3	3		393	348	362	379	333	351	342	296	316	368	322	337
MEAN				380	340	352	381	340	355	351	310	327	370	329	342

TABLE 58. MAIN EFFECTS OF EACH ECONOMIC FACTOR - AVERAGE PROFIT PER PERIOD PER COW

PRICE LEVELS[a] MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
			40-COW HERD, LOW-PRODUCTION LEVEL												
1				-3	-32	-26	-9	-38	-30	-42	-75	-64	-20	-49	-43
2				64	31	38	62	28	39	22	-14	-1	50	16	24
3				200	157	169	206	162	178	152	105	125	191	148	161
	1			178	140	150	180	141	155	133	92	108	167	128	139
	2			96	61	69	95	59	71	52	13	28	83	47	56
	3			-13	-45	-38	-17	-49	-39	-55	-90	-77	-29	-60	-53
		1		108	74	82	126	90	102	83	44	59	113	78	87
		2		87	52	60	86	50	62	43	5	19	73	38	47
		3		65	30	38	46	11	22	4	-34	-19	33	-1	7
				87	52	60	86	50	62	43	5	19	73	38	47
2	2	2		73	40	47	72	37	48	31	-6	7	59	25	33
			120-COW HERD, LOW-PRODUCTION LEVEL												
1				92	63	68	88	58	66	55	23	33	77	48	54
2				160	126	134	159	125	136	120	83	96	147	114	122
3				295	252	265	302	259	275	250	204	223	288	245	258
	1			274	236	246	277	239	252	231	190	206	264	226	237
	2			191	156	165	193	157	168	151	112	126	180	145	154
	3			81	50	57	79	47	57	43	8	20	68	37	44
		1		204	169	177	221	185	197	179	141	155	209	174	183
		2		182	147	156	183	148	159	142	103	117	171	136	145
		3		160	125	134	145	110	121	104	65	80	133	98	107
				182	147	156	183	148	159	142	103	117	171	136	145
2	2	2		169	135	143	169	134	145	129	92	105	157	123	131

[a] A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 59. MAIN EFFECTS OF EACH ECONOMIC FACTOR - AVERAGE PROFIT PER PERIOD PER COW

PRICE LEVELS[a] MILK	FEED	REAR	COW SEL.	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
			40-COW HERD, MEDIUM-PRODUCTION LEVEL												
1				82	52	59	75	43	52	49	17	29	65	33	40
2				162	127	136	160	122	135	126	88	104	149	111	122
3				323	278	292	329	281	300	280	232	254	316	268	284
	1			290	249	261	292	248	264	250	207	225	279	236	250
	2			199	162	172	199	159	173	161	122	138	187	147	159
	3			79	46	54	75	39	50	43	8	22	64	29	38
		1		211	174	184	229	190	203	192	153	170	218	179	190
		2		189	152	162	188	149	162	151	112	129	177	138	149
		3		167	131	141	147	108	121	110	71	88	136	97	108
				189	152	162	188	149	162	151	112	129	177	138	149
2	2	2		173	137	146	170	132	145	136	98	113	159	121	132
			120-COW HERD, MEDIUM-PRODUCTION LEVEL												
1				177	146	153	174	141	151	143	111	122	163	131	138
2				257	222	231	258	221	233	220	182	197	246	209	219
3				417	372	386	427	379	398	373	326	347	413	366	381
	1			384	344	355	390	347	362	343	301	319	376	334	347
	2			294	256	267	297	257	271	255	216	232	284	245	256
	3			173	140	148	173	137	148	137	102	116	161	127	135
		1		305	269	279	325	286	299	284	245	261	313	274	285
		2		284	247	257	286	247	260	245	206	222	274	235	246
		3		262	225	235	247	208	221	206	167	183	235	196	207
				284	247	257	286	247	260	245	206	222	274	235	246
2	2	2		267	231	241	269	230	243	229	192	207	256	219	229

[a]A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 60. MAIN EFFECTS OF EACH ECONOMIC FACTOR - AVERAGE PROFIT PER PERIOD PER COW

PRICE LEVELS[a] MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
			40-COW HERD, HIGH-PRODUCTION LEVEL												
1				162	129	137	154	120	130	138	105	118	144	110	118
2				255	216	227	251	212	225	227	188	204	240	201	212
3				440	391	407	446	395	415	404	354	377	433	382	399
	1			395	351	364	396	351	368	363	318	338	384	339	353
	2			297	256	268	295	253	268	267	226	244	284	242	254
	3			166	129	139	160	123	135	139	103	117	149	113	122
		1		308	267	279	326	285	299	299	258	275	315	274	285
		2		286	245	257	284	242	257	257	215	233	272	231	243
		3		264	223	235	241	200	215	214	173	191	230	189	201
				286	245	257	284	242	257	257	215	233	272	231	243
2	2	2		266	227	238	262	223	236	238	198	215	251	212	223
			120-COW HERD, HIGH-PRODUCTION LEVEL												
1				257	224	232	252	218	229	233	200	213	242	209	217
2				350	311	322	349	310	324	322	283	299	338	300	311
3				535	486	502	543	493	513	499	448	472	531	481	498
	1			490	445	459	494	449	466	458	413	433	482	437	452
	2			392	351	363	393	351	367	362	321	338	382	341	353
	3			261	225	234	258	221	234	234	198	212	248	212	221
		1		403	362	374	422	381	396	392	351	368	411	370	382
		2		381	340	352	381	340	355	351	310	328	370	330	342
		3		359	318	330	341	300	315	311	270	287	330	289	302
				381	340	352	381	340	355	351	310	328	370	330	342
2	2	2		361	322	333	360	321	335	332	293	309	349	310	322

[a] A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 61. PROFIT PER COW IN PERIOD 20: 40-COW HERD, LOW-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		162	126	162	178	135	185	133	97	144	167	124	169
1	1	2		140	104	140	138	95	145	93	57	104	127	84	130
1	1	3		118	83	118	98	56	106	53	18	65	87	44	90
1	2	1		75	43	75	88	49	95	48	16	58	78	39	80
1	2	2		53	21	53	49	10	55	8	-23	18	39	0	40
1	2	3		31	0	31	9	-29	15	-31	-63	-21	0	-40	1
1	3	1		-40	-67	-40	-29	-64	-25	-64	-92	-56	-39	-74	-38
1	3	2		-62	-89	-62	-69	-104	-64	-104	-132	-96	-78	-113	-78
1	3	3		-83	-111	-84	-109	-143	-104	-144	-171	-136	-118	-153	-117
2	1	1		236	195	238	256	208	265	204	163	218	244	196	248
2	1	2		214	174	216	217	168	226	164	123	178	205	156	208
2	1	3		193	152	194	177	128	186	125	83	138	165	116	169
2	2	1		150	112	150	167	122	175	119	81	131	156	111	159
2	2	2		128	90	128	127	82	135	80	42	92	116	71	119
2	2	3		106	68	107	88	43	96	40	2	52	76	31	79
2	3	1		34	1	34	48	8	55	6	-26	16	38	-2	40
2	3	2		12	-20	12	8	-31	15	-33	-66	-22	-1	-41	0
2	3	3		-9	-42	-9	-30	-71	-24	-72	-106	-62	-41	-81	-39
3	1	1		385	334	388	413	354	426	347	294	365	400	340	406
3	1	2		364	312	367	374	314	386	307	255	325	360	300	366
3	1	3		342	290	345	334	274	347	267	215	285	320	260	326
3	2	1		299	250	301	324	268	336	262	213	278	311	255	316
3	2	2		277	228	279	284	228	296	222	173	239	271	215	277
3	2	3		255	207	258	245	188	256	182	133	199	232	175	237
3	3	1		183	139	185	205	154	215	149	104	163	193	141	197
3	3	2		161	117	163	165	114	176	109	65	124	153	102	158
3	3	3		139	96	141	126	74	136	69	25	84	114	62	118
MEAN				142	103	143	143	97	152	93	54	106	132	85	135

TABLE 62. PROFIT PER COW IN PERIOD 20: 40-COW HERD, MEDIUM-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		260	213	261	277	230	276	237	198	250	267	219	261
1	1	2		238	191	239	236	189	235	196	157	209	226	178	220
1	1	3		216	169	217	195	148	194	155	116	168	185	137	179
1	2	1		165	122	165	179	136	177	144	109	156	170	126	163
1	2	2		143	100	143	138	95	136	103	68	115	129	85	122
1	2	3		121	78	121	97	54	95	62	27	74	88	44	81
1	3	1		38	1	38	48	11	45	21	-8	30	40	2	32
1	3	2		16	-20	16	8	-29	4	-19	-49	-10	0	-38	-8
1	3	3		-5	-42	-5	-32	-70	-36	-60	-90	-51	-41	-79	-49
2	1	1		347	295	349	369	315	370	321	276	337	358	304	354
2	1	2		326	273	328	328	274	329	280	235	296	317	263	313
2	1	3		304	251	306	287	233	288	239	194	255	276	222	272
2	2	1		252	204	254	271	222	271	228	187	242	261	211	256
2	2	2		231	182	232	230	181	230	187	146	201	220	170	215
2	2	3		209	160	210	189	140	189	146	105	160	179	129	174
2	3	1		126	82	126	140	97	139	105	69	117	131	87	125
2	3	2		104	60	105	100	56	98	64	28	76	90	46	84
2	3	3		82	38	83	59	15	57	23	-12	35	49	5	43
3	1	1		523	458	527	553	487	558	489	431	509	540	474	539
3	1	2		501	436	505	512	446	517	448	390	468	499	433	498
3	1	3		479	414	483	471	405	476	407	349	427	458	392	457
3	2	1		428	367	431	455	393	459	396	342	415	443	381	441
3	2	2		406	345	409	414	352	418	355	301	374	402	340	400
3	2	3		384	323	388	373	311	377	314	260	333	361	299	359
3	3	1		301	245	304	324	268	327	272	224	289	314	257	310
3	3	2		279	224	282	283	227	286	231	183	248	273	216	269
3	3	3		258	202	260	243	186	245	190	142	207	232	175	228
MEAN				249	198	250	249	198	250	204	162	219	239	188	234

TABLE 63. PROFIT PER COW IN PERIOD 20: 40-COW HERD, HIGH-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		351	301	353	360	319	370	339	297	354	350	309	354
1	1	2		329	279	331	317	277	328	297	255	312	308	266	312
1	1	3		307	257	309	275	235	286	254	213	269	265	224	270
1	2	1		248	202	249	253	217	262	238	201	252	244	208	247
1	2	2		226	180	227	211	175	220	196	159	209	202	165	205
1	2	3		204	158	205	169	133	178	154	117	167	159	123	163
1	3	1		110	70	110	111	81	118	104	73	115	103	72	105
1	3	2		88	48	88	69	39	76	62	31	73	61	30	63
1	3	3		66	26	66	27	-2	34	20	-11	30	18	-11	20
2	1	1		452	395	454	465	417	478	435	387	453	454	406	460
2	1	2		430	373	433	423	375	435	393	344	411	412	364	418
2	1	3		408	351	411	380	333	393	351	302	368	370	322	376
2	2	1		348	296	350	358	315	370	334	290	350	348	305	353
2	2	2		326	274	329	316	273	327	292	248	308	306	263	311
2	2	3		305	252	307	274	231	285	250	206	266	264	220	269
2	3	1		210	164	212	216	180	226	200	162	214	207	170	211
2	3	2		189	142	190	174	137	183	158	120	172	165	128	168
2	3	3		167	120	168	132	95	141	116	78	129	123	85	126
3	1	1		653	582	658	675	614	693	627	565	651	663	601	672
3	1	2		631	560	636	633	572	650	585	523	608	621	559	630
3	1	3		609	539	614	591	530	608	543	481	566	579	517	587
3	2	1		549	483	554	569	512	585	527	469	548	557	500	565
3	2	2		528	461	532	527	470	542	484	427	506	515	458	523
3	2	3		506	440	510	484	428	500	442	384	464	473	415	481
3	3	1		412	351	415	427	376	441	392	341	412	416	365	423
3	3	2		390	330	393	385	334	398	350	298	369	374	323	380
3	3	3		368	308	371	342	292	356	308	256	327	332	280	338
MEAN				348	294	350	339	294	351	313	267	329	329	283	334

TABLE 64. PROFIT PER COW IN PERIOD 20: 120-COW HERD, LOW-PRODUCTION LEVEL

PRICE LEVELS M I L K	F E E D	R E A R	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		257	221	257	273	230	280	229	193	240	262	219	264
1	1	2		235	200	235	235	193	242	191	155	202	224	181	227
1	1	3		213	178	214	197	155	204	153	118	164	187	144	189
1	2	1		170	138	170	184	145	190	144	112	154	174	134	175
1	2	2		148	116	148	146	107	152	106	74	116	136	97	138
1	2	3		126	94	126	108	69	114	69	36	78	98	59	100
1	3	1		55	27	54	65	31	70	31	3	39	56	21	57
1	3	2		33	5	32	27	-6	32	-6	-33	1	18	-16	19
1	3	3		11	-15	10	-9	-44	-5	-44	-71	-36	-19	-53	-18
2	1	1		331	290	333	351	303	360	300	259	313	340	291	343
2	1	2		309	268	311	314	265	322	263	221	275	302	253	305
2	1	3		288	247	289	276	227	284	225	183	237	264	215	267
2	2	1		245	207	245	262	217	270	216	178	227	251	206	254
2	2	2		223	185	224	224	180	232	178	140	189	213	168	216
2	2	3		201	163	202	187	142	194	140	102	151	175	130	178
2	3	1		129	96	129	144	103	150	103	69	112	133	93	135
2	3	2		107	74	107	106	66	112	65	31	74	96	55	97
2	3	3		85	53	86	68	28	74	27	-6	36	58	17	59
3	1	1		480	428	483	508	448	520	443	391	460	494	434	500
3	1	2		458	406	461	470	410	482	405	353	422	456	396	462
3	1	3		436	385	439	432	373	444	367	315	384	419	359	424
3	2	1		394	345	396	419	363	430	358	309	374	406	350	411
3	2	2		372	323	374	381	325	392	320	271	336	368	312	373
3	2	3		350	301	352	343	287	354	283	234	298	330	274	335
3	3	1		278	234	280	300	249	310	245	201	259	288	236	292
3	3	2		256	212	258	262	211	272	207	163	221	250	199	254
3	3	3		234	190	236	224	173	234	170	125	183	212	161	216
MEAN				237	198	238	240	194	248	192	152	204	229	182	232

TABLE 65. PROFIT PER COW IN PERIOD 20: 120-COW HERD, MEDIUM-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL / SIRE SEL	1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1	1	1		354	307	355	373	326	372	329	290	342	362	315	356
1	1	2		332	285	333	334	287	333	290	251	302	323	276	317
1	1	3		310	263	311	295	248	294	251	212	263	284	236	278
1	2	1		259	216	259	275	232	273	236	201	247	265	222	258
1	2	2		237	194	238	236	193	234	197	162	208	226	183	219
1	2	3		215	172	216	197	154	195	158	123	169	187	144	180
1	3	1		132	95	132	145	107	141	113	83	122	136	98	128
1	3	2		111	73	110	106	68	102	74	44	83	97	59	89
1	3	3		89	51	88	67	29	63	34	5	44	58	20	50
2	1	1		441	389	443	465	411	466	413	368	428	453	399	448
2	1	2		419	367	421	426	372	427	374	329	389	414	360	409
2	1	3		398	345	400	387	333	388	334	289	350	375	321	370
2	2	1		346	298	348	367	318	367	320	279	334	356	306	350
2	2	2		325	276	326	328	279	328	281	240	294	317	267	311
2	2	3		303	254	304	289	240	289	242	201	255	278	228	272
2	3	1		220	176	221	237	193	235	196	160	208	227	182	220
2	3	2		198	154	199	198	154	196	157	121	169	188	143	181
2	3	3		176	133	177	159	115	157	118	82	130	148	104	142
3	1	1		616	551	620	648	583	653	580	523	600	635	569	633
3	1	2		594	530	598	609	544	614	541	484	561	596	529	593
3	1	3		573	508	576	570	504	575	502	445	522	556	490	554
3	2	1		521	460	525	551	489	554	488	434	506	538	476	535
3	2	2		500	439	503	512	450	515	449	395	467	499	436	496
3	2	3		478	417	481	473	411	476	409	356	428	460	397	457
3	3	1		395	339	398	420	364	422	364	316	380	408	352	404
3	3	2		373	317	376	381	325	383	325	277	341	369	313	365
3	3	3		351	295	354	342	286	344	286	238	302	330	273	326
MEAN				343	292	344	347	296	348	298	255	312	336	285	331

TABLE 66. PROFIT PER COW IN PERIOD 20: 120-COW HERD, HIGH-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		446	396	448	455	415	465	432	390	447	446	405	450
1	1	2		424	374	426	415	375	425	392	350	406	405	364	409
1	1	3		402	352	404	375	334	385	351	310	366	365	324	369
1	2	1		343	297	344	349	313	358	331	294	344	340	304	343
1	2	2		321	275	322	309	273	317	291	254	304	300	263	303
1	2	3		299	253	300	268	233	277	251	213	264	259	223	262
1	3	1		205	165	205	207	177	214	197	166	208	199	169	201
1	3	2		183	143	183	167	137	174	157	126	167	159	128	161
1	3	3		161	121	162	127	97	133	117	85	127	118	88	120
2	1	1		546	489	549	560	513	573	528	479	545	550	502	555
2	1	2		525	467	527	520	473	532	487	439	505	510	462	515
2	1	3		503	446	505	480	432	492	447	399	465	469	421	475
2	2	1		443	390	445	454	411	465	427	383	443	444	401	449
2	2	2		421	369	423	414	371	424	387	343	403	404	361	408
2	2	3		399	347	402	373	331	384	347	303	362	364	320	368
2	3	1		306	259	307	312	275	321	293	255	306	303	266	307
2	3	2		284	237	285	272	235	281	253	215	266	263	226	266
2	3	3		262	215	263	232	195	240	213	174	226	223	185	226
3	1	1		747	677	752	770	709	787	720	658	743	758	697	767
3	1	2		725	655	730	730	669	747	679	617	702	718	656	726
3	1	3		704	633	708	690	629	706	639	577	662	678	616	686
3	2	1		644	578	648	664	607	679	619	562	640	653	595	660
3	2	2		622	556	626	624	567	639	579	521	600	612	555	620
3	2	3		600	534	604	583	527	599	538	481	560	572	515	579
3	3	1		506	446	510	522	472	535	485	433	504	512	461	518
3	3	2		484	424	488	482	431	495	445	393	463	471	420	478
3	3	3		463	402	466	442	391	455	404	353	423	431	380	437
MEAN				443	388	445	436	392	448	407	361	424	426	381	431

TABLE 67. MAIN EFFECTS OF EACH ECONOMIC FACTOR - PROFIT PER COW IN PERIOD 20

PRICE LEVELS[a] MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
			40-COW HERD, LOW-PRODUCTION LEVEL												
1				43	12	43	39	0	45	0	-32	8	29	-9	30
2				118	81	119	117	73	125	70	33	82	106	62	109
3				267	219	270	274	219	286	213	164	229	262	205	267
	1			239	197	241	243	192	252	188	145	202	231	180	235
	2			153	113	154	153	107	162	103	64	116	142	95	145
	3			37	2	37	35	-7	42	-9	-44	1	24	-17	26
		1		165	126	166	183	137	192	134	94	146	172	125	175
		2		143	104	144	144	97	152	94	55	106	132	86	135
		3		121	82	122	104	57	112	54	15	67	92	46	96
				144	104	144	144	98	152	94	54	106	133	86	136
2	2	2		128	90	128	127	82	135	80	42	92	116	71	119
			120-COW HERD, LOW-PRODUCTION LEVEL												
1				139	107	139	136	97	142	97	65	106	126	87	128
2				213	176	214	215	170	222	168	131	180	204	159	206
3				362	314	364	371	315	382	311	262	327	358	302	363
	1			334	291	336	340	289	349	286	243	300	327	277	331
	2			248	208	249	251	204	259	202	162	214	239	192	242
	3			132	97	132	132	90	139	88	53	99	121	79	123
		1		260	221	261	278	232	286	230	191	242	267	221	270
		2		238	199	239	241	194	249	192	153	204	229	183	232
		3		216	177	217	203	157	211	154	115	166	191	145	194
				238	199	239	241	195	249	193	153	204	230	183	233
2	2	2		223	185	224	224	180	232	178	140	189	213	168	216

[a] A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 68. MAIN EFFECTS OF EACH ECONOMIC FACTOR - PROFIT PER COW IN PERIOD 20

PRICE LEVELS[a] MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
				40-COW HERD, MEDIUM-PRODUCTION LEVEL											
1				132	90	133	127	85	125	93	58	104	118	75	111
2				220	172	221	219	170	219	177	136	191	209	160	204
3				396	335	399	403	342	407	345	291	363	391	330	389
	1			355	300	357	358	303	361	308	261	324	347	292	343
	2			260	209	262	261	209	262	215	172	230	250	199	245
	3			133	88	134	130	84	129	91	53	104	121	74	115
		1		271	221	273	291	240	291	246	203	261	280	229	275
		2		249	199	251	250	199	251	205	162	220	239	188	234
		3		227	177	229	209	158	210	164	121	179	198	147	193
				251	200	252	251	200	252	206	163	221	241	189	236
2	2	2		231	182	232	230	181	230	187	146	201	220	170	215
				120-COW HERD, MEDIUM-PRODUCTION LEVEL											
1				226	184	227	225	183	223	187	152	198	215	172	208
2				314	266	315	317	268	317	271	230	284	306	257	300
3				489	428	492	501	439	504	438	385	456	488	426	485
	1			449	394	451	456	401	458	402	354	417	444	388	440
	2			354	303	355	359	307	359	309	266	323	347	295	342
	3			227	182	228	228	182	227	185	147	198	218	172	212
		1		365	315	367	387	336	387	338	295	352	375	324	370
		2		343	293	345	348	297	348	299	256	313	336	285	331
		3		321	271	323	309	258	309	259	217	274	297	246	292
				344	293	346	349	298	349	299	256	313	337	286	332
2	2	2		325	276	326	328	279	328	281	240	294	317	267	311

[a] A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 69. MAIN EFFECTS OF EACH ECONOMIC FACTOR - PROFIT PER COW IN PERIOD 20

PRICE LEVELS[a] MILK	FEED	REAR												
		COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
		SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
			40-COW HERD, HIGH-PRODUCTION LEVEL											
1			214	169	215	199	164	208	185	148	198	190	154	193
2			315	263	317	304	262	315	281	237	297	294	251	299
3			516	450	520	515	459	530	473	416	495	503	446	511
	1		463	404	466	458	408	471	425	374	444	447	396	453
	2		360	305	362	351	306	363	324	278	341	341	295	346
	3		222	173	224	209	170	219	190	150	204	200	160	204
		1	370	316	373	382	337	393	355	309	372	371	326	377
		2	348	294	351	339	295	351	313	267	330	329	284	334
		3	327	272	329	297	252	309	271	225	287	287	242	292
			351	296	353	342	297	353	315	269	332	331	286	336
2	2	2	326	274	329	316	273	327	292	248	308	306	263	311
			120-COW HERD, HIGH-PRODUCTION LEVEL											
1			309	264	310	297	262	305	280	243	292	288	252	291
2			410	358	412	402	360	412	376	332	391	392	349	397
3			611	545	615	612	556	627	568	511	589	601	544	608
	1		558	499	561	555	505	568	519	469	538	544	494	550
	2		455	400	457	449	404	460	419	373	435	439	393	444
	3		317	268	319	307	268	316	285	245	299	298	258	301
		1	465	411	468	477	433	489	448	402	464	467	422	472
		2	443	389	446	437	392	448	408	362	424	427	382	432
		3	421	367	424	397	352	408	367	322	384	387	341	391
			444	390	447	438	393	449	409	363	425	428	383	433
2	2	2	421	369	423	414	371	424	387	343	403	404	361	408

[a] A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 70. PRESENT VALUE OF TOTAL PROFIT PER COW: 40-COW HERD, LOW-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		941	649	660	1087	791	816	714	394	440	964	672	680
1	1	2		726	435	446	697	401	426	324	4	50	574	282	290
1	1	3		512	220	231	307	11	36	-65	-385	-339	184	-107	-99
1	2	1		142	-124	-121	264	-4	8	-69	-363	-329	149	-116	-117
1	2	2		-71	-338	-336	-125	-394	-381	-459	-753	-719	-240	-506	-507
1	2	3		-286	-553	-550	-515	-784	-770	-849	-1143	-1109	-630	-896	-897
1	3	1		-921	-1156	-1164	-832	-1067	-1067	-1115	-1375	-1356	-936	-1168	-1182
1	3	2		-1136	-1370	-1379	-1222	-1457	-1457	-1505	-1765	-1746	-1326	-1558	-1572
1	3	3		-1351	-1585	-1594	-1612	-1846	-1847	-1895	-2155	-2136	-1716	-1948	-1962
2	1	1		1588	1257	1281	1773	1435	1476	1335	973	1037	1638	1305	1328
2	1	2		1374	1042	1066	1383	1045	1086	945	583	647	1248	915	938
2	1	3		1159	827	852	993	655	696	555	193	257	858	525	548
2	2	1		790	483	499	950	638	669	551	214	267	824	516	530
2	2	2		575	268	284	560	248	279	161	-175	-122	434	126	140
2	2	3		360	53	69	170	-141	-110	-228	-565	-512	44	-263	-249
2	3	1		-274	-548	-543	-146	-423	-407	-494	-796	-758	-262	-535	-534
2	3	2		-489	-763	-758	-536	-813	-796	-884	-1186	-1148	-652	-925	-924
2	3	3		-703	-978	-973	-926	-1203	-1186	-1274	-1576	-1538	-1042	-1315	-1314
3	1	1		2884	2472	2523	3144	2722	2797	2578	2130	2232	2988	2571	2624
3	1	2		2669	2257	2308	2754	2332	2407	2188	1740	1842	2598	2181	2234
3	1	3		2454	2042	2094	2365	1942	2017	1798	1350	1452	2208	1791	1844
3	2	1		2085	1698	1741	2321	1925	1990	1793	1371	1462	2173	1782	1826
3	2	2		1870	1483	1526	1932	1535	1600	1403	981	1072	1783	1392	1436
3	2	3		1656	1268	1311	1542	1145	1210	1013	591	682	1393	1002	1046
3	3	1		1020	666	697	1224	863	914	747	360	435	1087	730	762
3	3	2		805	451	483	834	473	524	357	-29	45	697	340	372
3	3	3		591	236	268	445	83	134	-32	-419	-344	307	-49	-17
MEAN				702	384	404	697	374	409	281	-66	-8	568	249	267

TABLE 71. PRESENT VALUE OF TOTAL PROFIT PER COW: 40-COW HERD, MEDIUM-PRODUCTION LEVEL

PRICE LEVELS M I L K	F E E D	R E A R	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		1867	1564	1583	2018	1694	1730	1715	1399	1453	1905	1585	1605
1	1	2		1653	1350	1368	1616	1292	1328	1312	996	1051	1502	1182	1202
1	1	3		1438	1135	1154	1214	890	926	910	594	648	1100	780	800
1	2	1		992	717	727	1116	822	846	858	571	612	1010	720	729
1	2	2		778	502	512	714	420	444	455	169	210	608	317	327
1	2	3		563	288	297	312	18	42	53	-233	-191	206	-84	-75
1	3	1		-174	-411	-415	-86	-340	-332	-284	-531	-507	-181	-432	-437
1	3	2		-388	-626	-629	-487	-742	-734	-687	-933	-910	-583	-835	-840
1	3	3		-603	-841	-844	-889	-1144	-1136	-1089	-1336	-1312	-986	-1237	-1242
2	1	1		2638	2290	2324	2829	2458	2514	2453	2089	2164	2706	2340	2377
2	1	2		2423	2075	2109	2428	2056	2112	2050	1687	1762	2304	1937	1974
2	1	3		2209	1861	1895	2026	1655	1710	1648	1285	1360	1901	1535	1572
2	2	1		1763	1443	1467	1928	1586	1629	1596	1262	1324	1812	1475	1501
2	2	2		1548	1228	1253	1526	1184	1228	1193	860	922	1410	1073	1099
2	2	3		1333	1014	1038	1124	783	826	791	457	519	1007	670	696
2	3	1		596	313	325	725	424	450	453	159	203	620	322	334
2	3	2		381	99	111	323	22	49	51	-243	-198	218	-80	-68
2	3	3		167	-115	-103	-77	-379	-352	-351	-645	-601	-184	-482	-470
3	1	1		4179	3742	3806	4453	3987	4081	3929	3471	3587	4310	3850	3921
3	1	2		3964	3527	3591	4051	3586	3679	3527	3068	3185	3907	3448	3519
3	1	3		3750	3313	3377	3649	3184	3277	3124	2666	2783	3505	3046	3116
3	2	1		3304	2895	2949	3551	3115	3197	3072	2643	2747	3416	2986	3046
3	2	2		3089	2680	2735	3149	2714	2795	2670	2241	2344	3013	2583	2643
3	2	3		2874	2465	2520	2748	2312	2393	2267	1838	1942	2611	2181	2241
3	3	1		2137	1765	1807	2349	1953	2018	1929	1540	1626	2224	1832	1878
3	3	2		1922	1551	1592	1947	1551	1616	1527	1138	1224	1821	1430	1476
3	3	3		1708	1336	1378	1545	1149	1214	1124	735	821	1419	1028	1073
MEAN				1707	1376	1404	1696	1342	1390	1344	997	1065	1577	1228	1258

TABLE 72. PRESENT VALUE OF TOTAL PROFIT PER COW: 40-COW HERD, HIGH-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL 1 SIRE SEL 1	COW SEL 1 SIRE SEL 2	COW SEL 1 SIRE SEL 3	COW SEL 2 SIRE SEL 1	COW SEL 2 SIRE SEL 2	COW SEL 2 SIRE SEL 3	COW SEL 3 SIRE SEL 1	COW SEL 3 SIRE SEL 2	COW SEL 3 SIRE SEL 3	COW SEL 4 SIRE SEL 1	COW SEL 4 SIRE SEL 2	COW SEL 4 SIRE SEL 3
1	1	1	2738	2400	2428	2892	2553	2593	2685	2356	2415	2783	2445	2468
1	1	2	2523	2185	2213	2477	2138	2178	2270	1941	2000	2368	2030	2053
1	1	3	2309	1970	1998	2062	1723	1764	1855	1526	1585	1952	1615	1637
1	2	1	1786	1479	1497	1910	1605	1631	1755	1459	1504	1809	1504	1515
1	2	2	1571	1265	1282	1495	1190	1217	1340	1044	1089	1394	1089	1100
1	2	3	1357	1050	1068	1080	776	802	925	629	674	979	674	685
1	3	1	517	253	256	601	341	349	515	264	289	510	250	245
1	3	2	302	38	41	186	-72	-65	100	-150	-125	95	-164	-169
1	3	3	88	-176	-173	-228	-487	-480	-314	-565	-540	-319	-579	-585
2	1	1	3629	3241	3286	3828	3437	3499	3538	3157	3239	3709	3320	3361
2	1	2	3414	3027	3071	3413	3022	3084	3123	2741	2824	3293	2905	2946
2	1	3	3199	2812	2857	2998	2608	2669	2708	2326	2409	2878	2489	2531
2	2	1	2677	2321	2355	2846	2489	2537	2608	2260	2328	2735	2379	2408
2	2	2	2462	2106	2141	2431	2074	2122	2193	1845	1913	2320	1964	1993
2	2	3	2248	1892	1926	2017	1660	1707	1778	1430	1498	1905	1549	1578
2	3	1	1408	1094	1114	1537	1226	1254	1369	1065	1113	1436	1125	1138
2	3	2	1193	880	899	1122	811	839	953	650	698	1021	710	723
2	3	3	979	665	685	707	396	424	538	235	282	606	295	308
3	1	1	5411	4925	5003	5700	5205	5309	5245	4758	4887	5560	5069	5148
3	1	2	5196	4710	4788	5286	4790	4894	4830	4343	4472	5145	4654	4732
3	1	3	4981	4495	4573	4871	4376	4479	4414	3928	4057	4730	4239	4317
3	2	1	4459	4005	4072	4719	4257	4347	4315	3862	3976	4587	4129	4195
3	2	2	4244	3790	3857	4304	3843	3932	3900	3447	3560	4171	3713	3780
3	2	3	4029	3575	3642	3889	3428	3518	3485	3031	3145	3756	3298	3365
3	3	1	3190	2778	2831	3409	2994	3065	3075	2666	2760	3288	2875	2925
3	3	2	2975	2563	2616	2994	2579	2650	2660	2251	2345	2873	2459	2509
3	3	3	2760	2348	2401	2580	2164	2235	2245	1836	1930	2458	2044	2094
MEAN			2653	2284	2323	2634	2263	2316	2374	2012	2086	2520	2151	2185

TABLE 73. PRESENT VALUE OF TOTAL PROFIT PER COW: 120-COW HERD, LOW-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL / SIRE SEL	1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1	1	1		1880	1586	1597	2024	1729	1753	1660	1341	1385	1908	1615	1625
1	1	2		1666	1372	1383	1653	1358	1382	1288	969	1014	1536	1244	1253
1	1	3		1451	1157	1168	1282	987	1011	917	598	642	1165	872	881
1	2	1		1082	813	816	1203	934	947	876	583	616	1095	828	828
1	2	2		868	598	601	832	563	576	504	211	244	723	456	456
1	2	3		653	384	386	461	192	205	132	-160	-127	351	84	84
1	3	1		18	-217	-226	108	-125	-126	-169	-428	-409	10	-222	-234
1	3	2		-195	-432	-440	-262	-496	-497	-541	-799	-781	-360	-594	-606
1	3	3		-410	-646	-655	-633	-867	-868	-912	-1171	-1153	-732	-965	-978
2	1	1		2527	2193	2217	2707	2370	2411	2282	1920	1983	2581	2246	2271
2	1	2		2312	1978	2002	2336	2000	2040	1910	1548	1611	2209	1875	1899
2	1	3		2097	1763	1788	1965	1629	1669	1538	1177	1239	1837	1503	1527
2	2	1		1729	1419	1435	1886	1575	1605	1497	1162	1213	1767	1459	1474
2	2	2		1514	1205	1221	1515	1204	1234	1126	790	841	1396	1087	1102
2	2	3		1299	990	1006	1144	833	863	754	418	470	1024	715	730
2	3	1		665	388	393	791	515	531	452	150	187	683	408	411
2	3	2		450	174	178	420	144	160	80	-220	-184	311	36	39
2	3	3		236	-40	-35	49	-226	-210	-291	-592	-556	-60	-334	-332
3	1	1		3820	3405	3457	4074	3653	3727	3525	3078	3177	3926	3508	3562
3	1	2		3605	3191	3242	3703	3282	3356	3153	2707	2806	3554	3137	3191
3	1	3		3390	2976	3027	3332	2911	2985	2781	2335	2434	3182	2765	2819
3	2	1		3022	2632	2675	3253	2858	2921	2741	2320	2408	3112	2721	2765
3	2	2		2807	2417	2460	2882	2487	2550	2369	1948	2036	2741	2349	2394
3	2	3		2592	2203	2246	2511	2116	2179	1997	1576	1664	2369	1977	2022
3	3	1		1958	1601	1633	2158	1797	1847	1695	1309	1381	2028	1670	1703
3	3	2		1743	1386	1418	1787	1426	1476	1323	937	1010	1656	1298	1331
3	3	3		1529	1171	1203	1416	1055	1105	951	565	638	1284	927	959
MEAN				1640	1320	1340	1651	1329	1364	1245	898	954	1529	1209	1228

TABLE 74. PRESENT VALUE OF TOTAL PROFIT PER COW: 120-COW HERD, MEDIUM-PRODUCTION LEVEL

PRICE LEVELS MILK FEED REAR	COW SEL 1 SIRE SEL 1	COW SEL 1 SIRE SEL 2	COW SEL 1 SIRE SEL 3	COW SEL 2 SIRE SEL 1	COW SEL 2 SIRE SEL 2	COW SEL 2 SIRE SEL 3	COW SEL 3 SIRE SEL 1	COW SEL 3 SIRE SEL 2	COW SEL 3 SIRE SEL 3	COW SEL 4 SIRE SEL 1	COW SEL 4 SIRE SEL 2	COW SEL 4 SIRE SEL 3
1 1 1	2796	2493	2512	2964	2641	2676	2618	2303	2356	2844	2527	2545
1 1 2	2581	2278	2297	2581	2258	2293	2234	1919	1972	2460	2143	2161
1 1 3	2366	2063	2082	2198	1875	1910	1850	1535	1588	2076	1760	1777
1 2 1	1922	1647	1656	2063	1770	1793	1761	1476	1516	1951	1664	1671
1 2 2	1707	1432	1441	1680	1387	1410	1377	1092	1132	1567	1280	1287
1 2 3	1492	1217	1227	1297	1004	1027	993	708	748	1183	896	903
1 3 1	757	519	516	862	608	615	619	373	396	761	512	505
1 3 2	542	304	301	479	225	232	235	-10	12	377	129	121
1 3 3	327	89	86	95	-157	-150	-148	-394	-371	-6	-254	-261
2 1 1	3565	3217	3251	3774	3405	3459	3356	2993	3067	3643	3280	3314
2 1 2	3350	3002	3036	3391	3021	3075	2972	2609	2683	3259	2896	2930
2 1 3	3135	2787	2821	3008	2638	2692	2588	2226	2299	2875	2513	2547
2 2 1	2691	2371	2395	2873	2533	2575	2499	2166	2227	2750	2417	2440
2 2 2	2476	2156	2181	2490	2150	2192	2115	1782	1843	2367	2033	2056
2 2 3	2261	1941	1966	2107	1767	1809	1731	1398	1459	1983	1649	1673
2 3 1	1525	1243	1255	1672	1372	1398	1357	1063	1107	1560	1265	1275
2 3 2	1311	1028	1040	1289	989	1015	973	680	723	1176	882	891
2 3 3	1096	813	825	906	605	631	589	296	339	793	498	507
3 1 1	5102	4665	4729	5395	4932	5023	4831	4374	4489	5242	4786	4854
3 1 2	4887	4450	4514	5012	4548	4640	4447	3990	4105	4858	4402	4470
3 1 3	4673	4235	4300	4629	4165	4257	4064	3607	3721	4474	4019	4086
3 2 1	4228	3819	3873	4494	4060	4140	3975	3547	3649	4349	3923	3980
3 2 2	4013	3604	3659	4111	3677	3757	3591	3163	3265	3965	3539	3596
3 2 3	3799	3389	3444	3728	3294	3374	3207	2780	2881	3581	3155	3212
3 3 1	3063	2691	2733	3293	2899	2962	2833	2445	2529	3159	2771	2814
3 3 2	2848	2476	2518	2910	2515	2579	2449	2061	2145	2775	2388	2430
3 3 3	2633	2261	2303	2527	2132	2196	2065	1677	1761	2391	2004	2046
MEAN	2635	2303	2331	2660	2307	2354	2265	1920	1986	2533	2188	2215

TABLE 75. PRESENT VALUE OF TOTAL PROFIT PER COW: 120-COW HERD, HIGH-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		3673	3335	3363	3835	3497	3544	3598	3270	3329	3728	3395	3421
1	1	2		3459	3120	3149	3439	3102	3148	3202	2874	2933	3332	2998	3024
1	1	3		3244	2906	2934	3043	2706	2752	2806	2478	2537	2936	2602	2628
1	2	1		2722	2416	2433	2854	2551	2583	2670	2375	2419	2755	2455	2469
1	2	2		2508	2201	2219	2459	2155	2187	2273	1978	2022	2359	2059	2073
1	2	3		2293	1986	2004	2063	1759	1791	1877	1582	1626	1963	1663	1676
1	3	1		1455	1190	1193	1547	1288	1302	1431	1181	1205	1458	1202	1200
1	3	2		1240	975	978	1151	892	906	1035	784	809	1062	806	804
1	3	3		1025	761	764	755	497	511	639	388	412	666	410	408
2	1	1		4563	4175	4220	4769	4380	4447	4450	4070	4152	4652	4268	4312
2	1	2		4348	3961	4006	4373	3984	4051	4054	3674	3755	4256	3871	3916
2	1	3		4134	3746	3791	3978	3588	3655	3658	3278	3359	3860	3475	3520
2	2	1		3612	3256	3290	3789	3433	3486	3522	3174	3241	3679	3328	3360
2	2	2		3397	3041	3075	3393	3037	3091	3125	2778	2845	3283	2932	2964
2	2	3		3183	2827	2861	2997	2641	2695	2729	2382	2449	2887	2536	2568
2	3	1		2344	2030	2050	2481	2171	2206	2283	1980	2027	2382	2075	2092
2	3	2		2129	1816	1835	2085	1775	1810	1887	1584	1631	1986	1679	1695
2	3	3		1915	1601	1621	1690	1379	1414	1491	1188	1235	1590	1283	1299
3	1	1		6342	5856	5934	6638	6145	6254	6154	5669	5797	6500	6014	6095
3	1	2		6127	5642	5719	6242	5749	5858	5758	5273	5401	6104	5618	5699
3	1	3		5913	5427	5505	5846	5353	5462	5362	4877	5004	5708	5221	5303
3	2	1		5391	4937	5004	5657	5198	5293	5226	4774	4886	5528	5074	5143
3	2	2		5176	4722	4789	5261	4802	4897	4829	4378	4490	5131	4678	4747
3	2	3		4962	4508	4575	4866	4406	4502	4433	3981	4094	4735	4282	4351
3	3	1		4123	3711	3764	4350	3935	4012	3987	3580	3673	4231	3822	3875
3	3	2		3909	3497	3549	3954	3540	3617	3591	3183	3276	3834	3425	3478
3	3	3		3694	3282	3335	3558	3144	3221	3195	2787	2880	3438	3029	3082
MEAN				3588	3219	3257	3595	3226	3285	3306	2945	3018	3483	3118	3155

TABLE 76. MAIN EFFECTS OF EACH ECONOMIC FACTOR - PRESENT VALUE OF TOTAL PROFIT PER COW

PRICE LEVELS[a] MILK	FEED	REAR	COW SEL 1 / SIRE SEL 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
			40-COW HERD, LOW-PRODUCTION LEVEL											
1			-160	-424	-423	-216	-483	-470	-547	-838	-804	-330	-594	-596
2			486	182	197	468	160	189	74	-259	-207	343	38	51
3			1782	1397	1439	1840	1447	1510	1316	897	986	1693	1304	1347
	1		1590	1245	1273	1611	1259	1306	1152	776	846	1473	1126	1154
	2		791	471	491	788	463	499	368	17	76	659	337	356
	3		-273	-560	-551	-308	-599	-576	-677	-993	-949	-427	-714	-708
		1	917	599	619	1087	764	799	671	323	381	958	639	657
		2	702	385	404	697	374	409	281	-66	-8	568	249	267
		3	488	170	189	307	-15	20	-108	-456	-398	178	-140	-122
			702	385	404	697	374	409	281	-66	-8	568	249	267
2	2	2	575	268	284	560	248	279	161	-175	-122	434	126	140
			120-COW HERD, LOW-PRODUCTION LEVEL											
1			779	512	514	740	475	487	417	127	158	633	368	367
2			1426	1119	1134	1424	1116	1144	1039	706	756	1305	999	1013
3			2718	2331	2373	2790	2398	2460	2282	1864	1950	2650	2261	2305
	1		2528	2180	2209	2564	2213	2259	2117	1741	1810	2433	2085	2114
	2		1730	1407	1427	1743	1418	1453	1333	983	1040	1620	1297	1317
	3		666	376	385	648	358	379	287	-27	14	535	247	254
		1	1856	1536	1555	2022	1701	1735	1617	1270	1327	1901	1581	1600
		2	1641	1321	1340	1651	1330	1364	1246	899	955	1529	1210	1229
		3	1426	1106	1126	1280	959	993	874	527	583	1158	838	857
			1641	1321	1340	1652	1330	1364	1246	899	955	1529	1210	1229
2	2	2	1514	1205	1221	1515	1204	1234	1126	790	841	1396	1087	1102

[a] A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 77. MAIN EFFECTS OF EACH ECONOMIC FACTOR - PRESENT VALUE OF TOTAL PROFIT PER COW

PRICE LEVELS[a] MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
				40-COW HERD, MEDIUM-PRODUCTION LEVEL											
1				680	408	417	614	323	346	360	77	117	509	221	229
2				1451	1134	1158	1426	1088	1129	1098	768	828	1310	976	1002
3				2992	2586	2639	3049	2617	2697	2574	2149	2251	2914	2487	2546
	1			2680	2317	2356	2698	2311	2373	2296	1917	1999	2571	2189	2232
	2			1805	1470	1500	1796	1439	1489	1439	1090	1159	1677	1324	1356
	3			638	341	358	594	277	310	297	-12	38	485	171	189
		1		1922	1591	1619	2098	1744	1792	1747	1400	1468	1980	1631	1661
		2		1708	1376	1405	1696	1342	1391	1344	998	1065	1578	1228	1259
		3		1493	1161	1190	1294	941	989	942	595	663	1175	826	856
				1708	1376	1405	1696	1343	1391	1344	998	1065	1578	1228	1259
2	2	2		1548	1228	1253	1526	1184	1228	1193	860	922	1410	1073	1099
				120-COW HERD, MEDIUM-PRODUCTION LEVEL											
1				1610	1338	1346	1580	1290	1312	1282	1000	1038	1468	1184	1190
2				2379	2062	2085	2390	2053	2094	2020	1690	1750	2267	1937	1959
3				3916	3510	3564	4011	3580	3659	3496	3071	3172	3866	3443	3499
	1			3606	3243	3282	3661	3276	3336	3218	2840	2920	3526	3147	3187
	2			2732	2397	2427	2760	2405	2453	2361	2013	2080	2633	2284	2313
	3			1567	1269	1286	1559	1243	1275	1219	910	960	1443	1133	1148
		1		2850	2518	2547	3044	2691	2738	2650	2304	2370	2918	2572	2600
		2		2635	2303	2332	2660	2308	2355	2266	1921	1987	2534	2188	2216
		3		2420	2089	2117	2277	1925	1972	1882	1537	1603	2150	1804	1832
				2635	2303	2332	2660	2308	2355	2266	1921	1987	2534	2188	2216
2	2	2		2476	2156	2181	2490	2150	2192	2115	1782	1843	2367	2033	2056

[a] A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 78. MAIN EFFECTS OF EACH ECONOMIC FACTOR - PRESENT VALUE OF TOTAL PROFIT PER COW

PRICE LEVELS[a] MILK	FEED	REAR	COW SEL / SIRE SEL	1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
			40-COW HERD, HIGH-PRODUCTION LEVEL												
1				1466	1163	1179	1386	1085	1110	1237	945	988	1286	985	994
2				2357	2004	2037	2322	1969	2015	2090	1745	1811	2211	1860	1887
3				4138	3688	3754	4195	3737	3826	3796	3347	3459	4063	3609	3674
	1			3711	3307	3358	3725	3317	3385	3408	3008	3099	3602	3196	3244
	2			2759	2387	2427	2743	2369	2424	2478	2112	2187	2628	2256	2291
	3			1490	1160	1185	1434	1105	1141	1238	917	972	1330	1002	1021
		1		2868	2500	2538	3049	2679	2732	2789	2427	2501	2935	2566	2600
		2		2654	2285	2323	2634	2264	2317	2374	2012	2086	2520	2151	2185
		3		2439	2070	2109	2219	1849	1902	1959	1597	1671	2105	1736	1770
				2654	2285	2323	2635	2264	2317	2375	2013	2086	2520	2151	2185
2	2	2		2462	2106	2141	2431	2074	2122	2193	1845	1913	2320	1964	1993
			120-COW HERD, HIGH-PRODUCTION LEVEL												
1				2402	2099	2115	2350	2050	2081	2170	1879	1921	2251	1954	1967
2				3292	2939	2972	3284	2932	2984	3022	2679	2744	3175	2828	2858
3				5071	4620	4686	5152	4697	4791	4726	4278	4389	5023	4574	4642
	1			4645	4241	4291	4685	4278	4352	4338	3940	4030	4564	4163	4213
	2			3694	3322	3361	3704	3331	3392	3409	3045	3119	3591	3223	3261
	3			2426	2096	2121	2397	2069	2111	2171	1851	1905	2294	1970	1993
		1		3803	3434	3473	3991	3622	3681	3702	3341	3414	3879	3515	3552
		2		3588	3219	3258	3595	3226	3285	3306	2945	3018	3483	3119	3156
		3		3373	3005	3043	3199	2830	2889	2910	2549	2622	3087	2722	2759
				3588	3219	3258	3595	3226	3285	3306	2945	3018	3483	3119	3156
2	2	2		3397	3041	3075	3393	3037	3091	3125	2778	2845	3283	2932	2964

[a] A BLANK DENOTES AVERAGED OVER THE LEVELS OF THE FACTOR

TABLE 79. CHANGE IN PROFIT PER PERIOD PER COW: 40-COW HERD, LOW-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		5.72	4.97	7.47	5.74	4.70	7.93	5.60	4.60	7.98	5.85	4.87	7.75
1	1	2		5.72	4.97	7.47	5.74	4.70	7.93	5.60	4.60	7.98	5.85	4.87	7.75
1	1	3		5.72	4.97	7.47	5.74	4.70	7.93	5.60	4.60	7.98	5.85	4.87	7.75
1	2	1		5.26	4.61	6.89	5.27	4.33	7.29	5.18	4.27	7.38	5.37	4.49	7.13
1	2	2		5.26	4.61	6.89	5.27	4.33	7.29	5.18	4.27	7.38	5.37	4.49	7.13
1	2	3		5.26	4.61	6.89	5.27	4.33	7.29	5.18	4.27	7.38	5.37	4.49	7.13
1	3	1		4.64	4.13	6.12	4.64	3.83	6.45	4.61	3.83	6.58	4.74	3.99	6.31
1	3	2		4.64	4.13	6.12	4.64	3.83	6.45	4.61	3.83	6.58	4.73	3.99	6.31
1	3	3		4.64	4.13	6.12	4.64	3.83	6.45	4.61	3.83	6.58	4.73	3.99	6.31
2	1	1		6.46	5.57	8.42	6.49	5.31	8.94	6.30	5.15	8.97	6.62	5.49	8.74
2	1	2		6.46	5.57	8.42	6.49	5.31	8.94	6.30	5.15	8.97	6.62	5.49	8.74
2	1	3		6.46	5.57	8.42	6.49	5.31	8.94	6.30	5.15	8.97	6.62	5.49	8.74
2	2	1		6.00	5.20	7.84	6.02	4.94	8.31	5.87	4.81	8.37	6.14	5.11	8.13
2	2	2		6.00	5.20	7.84	6.02	4.94	8.31	5.87	4.81	8.37	6.14	5.11	8.13
2	2	3		6.00	5.20	7.84	6.02	4.94	8.31	5.87	4.81	8.37	6.14	5.11	8.13
2	3	1		5.39	4.72	7.06	5.40	4.44	7.47	5.31	4.37	7.56	5.50	4.60	7.31
2	3	2		5.39	4.72	7.06	5.40	4.44	7.47	5.31	4.37	7.56	5.50	4.60	7.31
2	3	3		5.39	4.72	7.06	5.40	4.44	7.47	5.31	4.37	7.56	5.50	4.60	7.31
3	1	1		7.95	6.75	10.30	8.00	6.52	10.98	7.68	6.24	10.94	8.16	6.72	10.73
3	1	2		7.95	6.75	10.30	8.00	6.52	10.98	7.68	6.24	10.94	8.16	6.72	10.73
3	1	3		7.95	6.75	10.30	8.00	6.52	10.98	7.68	6.24	10.94	8.16	6.72	10.73
3	2	1		7.49	6.39	9.72	7.53	6.14	10.35	7.26	5.91	10.34	7.68	6.34	10.11
3	2	2		7.49	6.39	9.72	7.53	6.14	10.35	7.26	5.91	10.34	7.68	6.34	10.11
3	2	3		7.49	6.39	9.72	7.53	6.14	10.35	7.26	5.91	10.34	7.68	6.34	10.11
3	3	1		6.88	5.91	8.95	6.91	5.65	9.51	6.69	5.47	9.54	7.04	5.83	9.29
3	3	2		6.88	5.91	8.95	6.91	5.65	9.51	6.69	5.47	9.54	7.04	5.83	9.29
3	3	3		6.88	5.91	8.95	6.91	5.65	9.51	6.69	5.47	9.54	7.04	5.83	9.29
MEAN				6.20	5.36	8.09	6.22	5.10	8.58	6.06	4.96	8.63	6.34	5.27	8.39

TABLE 80. CHANGE IN PROFIT PER PERIOD PER COW: 40-COW HERD, MEDIUM-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL / SIRE SEL	1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1	1	1		5.87	4.84	7.60	6.00	4.64	8.08	5.54	4.23	7.88	6.10	4.80	7.99
1	1	2		5.87	4.84	7.60	6.00	4.64	8.08	5.54	4.23	7.88	6.10	4.80	7.99
1	1	3		5.87	4.84	7.60	6.00	4.64	8.08	5.54	4.23	7.88	6.10	4.80	7.99
1	2	1		5.37	4.45	6.96	5.49	4.25	7.39	5.08	3.87	7.21	5.59	4.39	7.32
1	2	2		5.37	4.45	6.96	5.49	4.25	7.39	5.08	3.87	7.21	5.59	4.39	7.32
1	2	3		5.37	4.45	6.96	5.49	4.25	7.39	5.08	3.87	7.21	5.59	4.39	7.32
1	3	1		4.71	3.93	6.12	4.81	3.71	6.46	4.46	3.40	6.33	4.90	3.85	6.42
1	3	2		4.71	3.93	6.12	4.81	3.71	6.46	4.46	3.40	6.33	4.90	3.85	6.42
1	3	3		4.71	3.93	6.12	4.81	3.71	6.46	4.46	3.40	6.33	4.90	3.85	6.42
2	1	1		6.67	5.46	8.61	6.80	5.28	9.18	6.27	4.80	8.94	6.92	5.45	9.06
2	1	2		6.67	5.46	8.61	6.80	5.28	9.18	6.27	4.80	8.94	6.92	5.45	9.06
2	1	3		6.67	5.46	8.61	6.80	5.28	9.18	6.27	4.80	8.94	6.92	5.45	9.06
2	2	1		6.17	5.07	7.98	6.29	4.88	8.48	5.81	4.45	8.28	6.40	5.04	8.39
2	2	2		6.17	5.07	7.98	6.29	4.88	8.48	5.81	4.45	8.28	6.40	5.04	8.39
2	2	3		6.17	5.07	7.98	6.29	4.88	8.48	5.81	4.45	8.28	6.40	5.04	8.39
2	3	1		5.50	4.55	7.13	5.61	4.35	7.56	5.20	3.97	7.39	5.71	4.50	7.49
2	3	2		5.50	4.55	7.13	5.61	4.35	7.56	5.20	3.97	7.39	5.71	4.50	7.49
2	3	3		5.50	4.55	7.13	5.61	4.35	7.56	5.20	3.97	7.39	5.71	4.50	7.49
3	1	1		8.25	6.71	10.64	8.40	6.55	11.37	7.74	5.95	11.07	8.56	6.74	11.20
3	1	2		8.25	6.71	10.64	8.40	6.55	11.37	7.74	5.95	11.07	8.56	6.74	11.20
3	1	3		8.25	6.71	10.64	8.40	6.55	11.37	7.74	5.95	11.07	8.56	6.74	11.20
3	2	1		7.75	6.32	10.00	7.89	6.15	10.68	7.28	5.59	10.40	8.04	6.34	10.53
3	2	2		7.75	6.32	10.00	7.89	6.15	10.68	7.28	5.59	10.40	8.04	6.34	10.53
3	2	3		7.75	6.32	10.00	7.89	6.15	10.68	7.28	5.59	10.40	8.04	6.34	10.53
3	3	1		7.09	5.80	9.16	7.22	5.62	9.75	6.66	5.12	9.52	7.35	5.80	9.62
3	3	2		7.09	5.80	9.16	7.22	5.62	9.75	6.66	5.12	9.52	7.35	5.80	9.62
3	3	3		7.09	5.80	9.16	7.22	5.62	9.75	6.66	5.12	9.52	7.35	5.80	9.63
MEAN				6.38	5.24	8.25	6.50	5.05	8.77	6.00	4.60	8.56	6.62	5.21	8.67

TABLE 81. CHANGE IN PROFIT PER PERIOD PER COW: 40-COW HERD, HIGH-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL 1 / SIRE SEL 1	COW SEL 1 / SIRE SEL 2	COW SEL 1 / SIRE SEL 3	COW SEL 2 / SIRE SEL 1	COW SEL 2 / SIRE SEL 2	COW SEL 2 / SIRE SEL 3	COW SEL 3 / SIRE SEL 1	COW SEL 3 / SIRE SEL 2	COW SEL 3 / SIRE SEL 3	COW SEL 4 / SIRE SEL 1	COW SEL 4 / SIRE SEL 2	COW SEL 4 / SIRE SEL 3
1	1	1	5.96	4.88	8.00	5.84	4.59	8.17	5.61	4.22	8.12	6.04	4.73	8.01
1	1	2	5.96	4.88	8.00	5.84	4.59	8.17	5.61	4.22	8.12	6.04	4.73	8.01
1	1	3	5.96	4.88	8.00	5.84	4.59	8.17	5.61	4.22	8.12	6.04	4.73	8.01
1	2	1	5.42	4.46	7.31	5.29	4.16	7.40	5.11	3.85	7.40	5.48	4.29	7.26
1	2	2	5.42	4.46	7.31	5.29	4.16	7.40	5.11	3.85	7.40	5.48	4.29	7.26
1	2	3	5.42	4.46	7.31	5.29	4.16	7.40	5.11	3.85	7.40	5.48	4.29	7.26
1	3	1	4.70	3.91	6.38	4.55	3.59	6.38	4.45	3.35	6.43	4.72	3.71	6.27
1	3	2	4.70	3.91	6.38	4.55	3.59	6.38	4.45	3.35	6.43	4.72	3.71	6.27
1	3	3	4.70	3.91	6.38	4.55	3.59	6.38	4.45	3.35	6.43	4.72	3.71	6.27
2	1	1	6.80	5.52	9.07	6.68	5.24	9.34	6.37	4.81	9.26	6.90	5.40	9.15
2	1	2	6.79	5.52	9.07	6.68	5.24	9.34	6.37	4.81	9.26	6.90	5.40	9.15
2	1	3	6.80	5.52	9.07	6.68	5.24	9.34	6.37	4.81	9.26	6.90	5.40	9.15
2	2	1	6.25	5.11	8.38	6.13	4.82	8.57	5.88	4.44	8.53	6.33	4.96	8.40
2	2	2	6.25	5.11	8.38	6.13	4.82	8.57	5.88	4.44	8.53	6.33	4.96	8.40
2	2	3	6.25	5.11	8.38	6.13	4.82	8.57	5.88	4.44	8.53	6.33	4.96	8.40
2	3	1	5.53	4.56	7.45	5.39	4.25	7.55	5.22	3.94	7.56	5.58	4.38	7.41
2	3	2	5.53	4.56	7.45	5.39	4.25	7.55	5.22	3.94	7.56	5.58	4.38	7.41
2	3	3	5.53	4.56	7.45	5.39	4.25	7.55	5.22	3.94	7.56	5.58	4.38	7.41
3	1	1	8.46	6.82	11.22	8.36	6.56	11.68	7.91	6.00	11.52	8.62	6.74	11.42
3	1	2	8.46	6.82	11.22	8.36	6.56	11.68	7.91	6.00	11.52	8.62	6.74	11.42
3	1	3	8.46	6.82	11.22	8.36	6.56	11.68	7.91	6.00	11.52	8.62	6.74	11.42
3	2	1	7.92	6.40	10.53	7.81	6.13	10.91	7.41	5.62	10.80	8.05	6.31	10.68
3	2	2	7.92	6.40	10.53	7.81	6.13	10.91	7.41	5.62	10.80	8.05	6.31	10.68
3	2	3	7.92	6.40	10.53	7.81	6.13	10.91	7.41	5.62	10.80	8.05	6.31	10.68
3	3	1	7.19	5.85	9.60	7.07	5.56	9.89	6.76	5.12	9.83	7.30	5.73	9.69
3	3	2	7.19	5.85	9.60	7.07	5.56	9.89	6.76	5.12	9.83	7.30	5.73	9.69
3	3	3	7.19	5.85	9.60	7.07	5.56	9.89	6.76	5.12	9.83	7.30	5.73	9.69
MEAN			6.47	5.28	8.66	6.35	4.99	8.88	6.08	4.60	8.83	6.56	5.14	8.70

TABLE 82. CHANGE IN PROFIT PER PERIOD PER COW: 120-COW HERD, LOW-PRODUCTION LEVEL

PRICE LEVELS MILK	FEED	REAR	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
			SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		5.72	4.94	7.44	5.72	4.68	7.87	5.59	4.58	7.92	5.80	4.90	7.71
1	1	2		5.72	4.94	7.44	5.72	4.68	7.87	5.59	4.58	7.92	5.80	4.90	7.71
1	1	3		5.72	4.94	7.44	5.72	4.68	7.87	5.59	4.58	7.92	5.80	4.90	7.71
1	2	1		5.26	4.58	6.86	5.25	4.31	7.24	5.17	4.25	7.32	5.32	4.53	7.10
1	2	2		5.26	4.58	6.86	5.25	4.31	7.24	5.17	4.25	7.32	5.32	4.53	7.10
1	2	3		5.26	4.58	6.86	5.25	4.31	7.24	5.17	4.25	7.32	5.32	4.53	7.10
1	3	1		4.65	4.10	6.10	4.63	3.82	6.40	4.60	3.81	6.52	4.69	4.03	6.28
1	3	2		4.65	4.10	6.10	4.63	3.82	6.40	4.60	3.81	6.52	4.69	4.03	6.28
1	3	3		4.65	4.10	6.10	4.63	3.82	6.40	4.60	3.81	6.52	4.69	4.03	6.28
2	1	1		6.46	5.53	8.38	6.47	5.29	8.88	6.29	5.12	8.90	6.56	5.51	8.69
2	1	2		6.46	5.53	8.38	6.47	5.29	8.88	6.29	5.12	8.90	6.56	5.51	8.69
2	1	3		6.46	5.53	8.38	6.47	5.29	8.88	6.29	5.12	8.90	6.56	5.51	8.69
2	2	1		6.00	5.17	7.80	6.01	4.91	8.25	5.86	4.79	8.30	6.09	5.14	8.08
2	2	2		6.00	5.17	7.80	6.01	4.91	8.25	5.86	4.79	8.30	6.09	5.14	8.08
2	2	3		6.00	5.17	7.80	6.01	4.91	8.25	5.86	4.79	8.30	6.09	5.14	8.08
2	3	1		5.39	4.69	7.03	5.38	4.42	7.41	5.30	4.35	7.50	5.46	4.64	7.27
2	3	2		5.39	4.69	7.03	5.38	4.42	7.41	5.30	4.35	7.50	5.46	4.64	7.27
2	3	3		5.39	4.69	7.03	5.38	4.42	7.41	5.30	4.35	7.50	5.46	4.64	7.27
3	1	1		7.94	6.71	10.26	7.98	6.49	10.90	7.67	6.21	10.86	8.09	6.73	10.66
3	1	2		7.94	6.71	10.26	7.98	6.49	10.90	7.67	6.21	10.86	8.09	6.73	10.66
3	1	3		7.94	6.71	10.26	7.98	6.49	10.90	7.67	6.21	10.86	8.09	6.73	10.66
3	2	1		7.48	6.35	9.68	7.51	6.12	10.27	7.25	5.88	10.26	7.61	6.36	10.05
3	2	2		7.48	6.35	9.68	7.51	6.12	10.27	7.25	5.88	10.26	7.61	6.36	10.05
3	2	3		7.48	6.35	9.68	7.51	6.12	10.27	7.25	5.88	10.26	7.61	6.36	10.05
3	3	1		6.88	5.87	8.91	6.89	5.62	9.44	6.68	5.45	9.46	6.98	5.86	9.24
3	3	2		6.88	5.87	8.91	6.89	5.62	9.44	6.68	5.45	9.46	6.98	5.86	9.24
3	3	3		6.88	5.87	8.91	6.89	5.62	9.44	6.68	5.45	9.46	6.98	5.86	9.24
MEAN				6.20	5.33	8.05	6.20	5.07	8.52	6.05	4.94	8.56	6.29	5.30	8.34

TABLE 83. CHANGE IN PROFIT PER PERIOD PER COW: 120-COW HERD, MEDIUM-PRODUCTION LEVEL

PRICE LEVELS			COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
MILK	FEED	REAR	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1		5.82	4.78	7.55	5.97	4.62	8.01	5.52	4.21	7.82	6.05	4.81	7.92
1	1	2		5.82	4.78	7.55	5.97	4.62	8.01	5.52	4.21	7.82	6.05	4.81	7.92
1	1	3		5.82	4.78	7.55	5.97	4.62	8.01	5.52	4.21	7.82	6.05	4.81	7.92
1	2	1		5.33	4.40	6.92	5.47	4.22	7.32	5.06	3.85	7.16	5.54	4.40	7.25
1	2	2		5.33	4.40	6.92	5.47	4.22	7.32	5.06	3.85	7.16	5.54	4.40	7.25
1	2	3		5.33	4.40	6.92	5.47	4.22	7.32	5.06	3.85	7.16	5.54	4.40	7.25
1	3	1		4.67	3.88	6.07	4.79	3.69	6.40	4.45	3.38	6.28	4.86	3.87	6.36
1	3	2		4.67	3.88	6.07	4.79	3.69	6.40	4.45	3.38	6.28	4.86	3.87	6.36
1	3	3		4.67	3.88	6.07	4.79	3.69	6.40	4.45	3.38	6.28	4.86	3.87	6.36
2	1	1		6.60	5.40	8.55	6.77	5.25	9.10	6.25	4.78	8.87	6.87	5.45	8.98
2	1	2		6.60	5.40	8.55	6.77	5.25	9.10	6.25	4.78	8.87	6.87	5.45	8.98
2	1	3		6.60	5.40	8.55	6.77	5.25	9.10	6.25	4.78	8.87	6.87	5.45	8.98
2	2	1		6.11	5.01	7.92	6.27	4.85	8.41	5.79	4.42	8.21	6.35	5.05	8.31
2	2	2		6.11	5.01	7.92	6.27	4.85	8.41	5.79	4.42	8.21	6.35	5.05	8.31
2	2	3		6.11	5.01	7.92	6.27	4.85	8.41	5.79	4.42	8.21	6.35	5.05	8.31
2	3	1		5.45	4.50	7.08	5.59	4.32	7.49	5.18	3.95	7.33	5.67	4.51	7.42
2	3	2		5.45	4.50	7.08	5.59	4.32	7.49	5.18	3.95	7.33	5.67	4.51	7.42
2	3	3		5.45	4.50	7.08	5.59	4.32	7.49	5.18	3.95	7.33	5.67	4.51	7.42
3	1	1		8.18	6.64	10.57	8.37	6.51	11.28	7.72	5.92	10.99	8.49	6.73	11.10
3	1	2		8.18	6.64	10.57	8.37	6.51	11.28	7.72	5.92	10.99	8.49	6.73	11.10
3	1	3		8.18	6.64	10.57	8.37	6.51	11.28	7.72	5.92	10.99	8.49	6.73	11.10
3	2	1		7.68	6.25	9.94	7.86	6.11	10.59	7.26	5.56	10.32	7.98	6.33	10.43
3	2	2		7.68	6.25	9.94	7.86	6.11	10.59	7.26	5.56	10.32	7.98	6.33	10.43
3	2	3		7.68	6.25	9.94	7.86	6.11	10.59	7.26	5.56	10.32	7.98	6.33	10.43
3	3	1		7.02	5.73	9.09	7.19	5.58	9.67	6.65	5.09	9.44	7.29	5.79	9.54
3	3	2		7.02	5.73	9.09	7.19	5.58	9.67	6.65	5.09	9.44	7.29	5.79	9.54
3	3	3		7.02	5.73	9.09	7.19	5.58	9.67	6.65	5.09	9.44	7.29	5.79	9.54
MEAN				6.32	5.18	8.19	6.48	5.02	8.70	5.99	4.57	8.49	6.57	5.22	8.59

TABLE 84. CHANGE IN PROFIT PER PERIOD PER COW: 120-COW HERD, HIGH-PRODUCTION LEVEL

PRICE LEVELS MILK FEED REAR	COW SEL / SIRE SEL 1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1 1 1	5.93	4.84	7.96	5.81	4.56	8.17	5.59	4.20	8.07	6.00	4.73	8.05
1 1 2	5.93	4.84	7.96	5.81	4.56	8.17	5.59	4.20	8.07	6.00	4.73	8.05
1 1 3	5.93	4.84	7.96	5.81	4.56	8.17	5.59	4.20	8.07	6.00	4.73	8.05
1 2 1	5.39	4.43	7.27	5.26	4.13	7.41	5.09	3.83	7.35	5.44	4.29	7.32
1 2 2	5.39	4.43	7.27	5.26	4.13	7.41	5.09	3.83	7.35	5.44	4.29	7.32
1 2 3	5.39	4.43	7.27	5.26	4.13	7.41	5.09	3.83	7.35	5.44	4.29	7.32
1 3 1	4.67	3.88	6.35	4.53	3.56	6.40	4.44	3.33	6.39	4.69	3.72	6.33
1 3 2	4.67	3.88	6.35	4.53	3.56	6.40	4.44	3.33	6.39	4.69	3.72	6.33
1 3 3	4.67	3.88	6.35	4.53	3.56	6.40	4.44	3.33	6.39	4.69	3.72	6.33
2 1 1	6.75	5.48	9.03	6.65	5.21	9.34	6.35	4.79	9.20	6.86	5.39	9.18
2 1 2	6.75	5.48	9.03	6.65	5.21	9.34	6.35	4.79	9.20	6.86	5.39	9.18
2 1 3	6.75	5.48	9.03	6.65	5.21	9.34	6.35	4.79	9.20	6.86	5.39	9.18
2 2 1	6.21	5.07	8.34	6.10	4.78	8.58	5.86	4.42	8.47	6.30	4.96	8.45
2 2 2	6.21	5.07	8.34	6.10	4.78	8.58	5.86	4.42	8.47	6.30	4.96	8.45
2 2 3	6.21	5.07	8.34	6.10	4.78	8.58	5.86	4.42	8.47	6.30	4.96	8.45
2 3 1	5.50	4.52	7.42	5.37	4.22	7.56	5.20	3.92	7.51	5.55	4.39	7.46
2 3 2	5.50	4.52	7.42	5.37	4.22	7.56	5.20	3.92	7.51	5.55	4.39	7.46
2 3 3	5.50	4.52	7.42	5.37	4.22	7.56	5.20	3.92	7.51	5.55	4.39	7.46
3 1 1	8.40	6.76	11.17	8.32	6.52	11.66	7.88	5.96	11.45	8.56	6.73	11.44
3 1 2	8.40	6.76	11.17	8.32	6.52	11.66	7.88	5.96	11.45	8.56	6.73	11.44
3 1 3	8.40	6.76	11.17	8.32	6.52	11.66	7.88	5.96	11.45	8.56	6.73	11.44
3 2 1	7.87	6.35	10.48	7.77	6.09	10.90	7.39	5.59	10.73	8.00	6.29	10.71
3 2 2	7.87	6.35	10.48	7.77	6.09	10.90	7.39	5.59	10.73	8.00	6.29	10.71
3 2 3	7.87	6.35	10.48	7.77	6.09	10.90	7.39	5.59	10.73	8.00	6.29	10.71
3 3 1	7.15	5.80	9.56	7.04	5.52	9.88	6.73	5.10	9.76	7.26	5.72	9.72
3 3 2	7.15	5.80	9.56	7.04	5.52	9.88	6.73	5.10	9.76	7.26	5.72	9.72
3 3 3	7.15	5.80	9.56	7.04	5.52	9.88	6.73	5.10	9.76	7.26	5.72	9.72
MEAN	6.43	5.24	8.62	6.32	4.95	8.88	6.06	4.57	8.77	6.52	5.14	8.74

TABLE 85. AVERAGE PROFIT PER COW AT THE MEDIUM LEVEL OF ALL ECONOMIC FACTORS
PERIODS 1 TO 20: 40-COW HERD, LOW-PRODUCTION LEVEL

PERIOD	COW SEL / SIRE SEL	1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1		14	-7	-17	12	-9	-20	-27	-48	-59	0	-23	-33
2		19	-2	-12	16	-4	-15	-22	-43	-54	4	-18	-28
3		25	1	-7	23	0	-10	-16	-40	-50	11	-13	-23
4		32	6	-2	32	4	-5	-8	-37	-47	18	-8	-18
5		39	11	2	40	9	0	0	-33	-42	26	-3	-12
6		46	16	9	48	14	7	5	-29	-35	33	1	-5
7		54	21	15	55	19	15	12	-24	-27	41	7	1
8		61	26	23	62	24	23	18	-20	-19	48	12	9
9		67	31	31	62	30	32	24	-15	-11	55	17	17
10		74	36	39	68	35	41	30	-10	-2	55	23	26
11		81	41	48	74	40	51	36	-5	7	61	28	35
12		87	47	57	81	46	53	42	0	16	68	34	45
13		93	52	66	87	51	63	48	4	26	74	39	47
14		92	57	76	93	57	73	53	10	36	80	45	57
15		98	63	85	99	62	83	59	15	47	86	50	67
16		104	68	88	104	68	94	64	20	57	92	56	77
17		110	74	98	110	66	104	70	26	67	98	61	88
18		116	79	108	116	71	114	76	31	71	104	60	98
19		122	85	118	122	77	125	74	36	81	110	65	108
20		128	90	128	127	82	135	80	42	92	116	71	119
CHANGE/PERIOD		6.00	5.20	7.84	6.02	4.94	8.31	5.87	4.81	8.37	6.14	5.11	8.13

TABLE 86. AVERAGE PROFIT PER COW AT THE MEDIUM LEVEL OF ALL ECONOMIC FACTORS PERIODS 1 TO 20: 40-COW HERD, MEDIUM-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		112	95	85	110	86	75	83	60	49	98	73	62
2		117	100	90	115	91	80	82	65	54	103	78	68
3		124	98	88	122	96	85	88	68	58	110	83	72
4		131	102	93	131	100	90	95	70	60	118	88	78
5		138	107	99	139	105	96	103	73	65	125	93	84
6		146	112	105	147	109	103	109	77	72	133	98	91
7		153	117	112	146	115	111	116	82	80	141	103	98
8		160	122	120	153	120	120	122	86	81	140	108	106
9		167	127	128	160	125	129	128	84	90	147	114	115
10		174	132	137	167	131	139	135	89	100	154	119	124
11		181	138	146	173	136	140	141	95	110	161	125	134
12		180	143	155	180	142	151	147	100	120	168	131	136
13		186	149	165	186	148	161	153	106	131	175	137	146
14		193	155	175	193	145	172	159	111	142	181	143	157
15		199	161	178	199	151	183	165	117	153	188	140	168
16		205	166	188	205	157	194	171	123	164	194	146	179
17		212	172	199	212	163	205	169	128	167	201	152	190
18		218	178	210	218	169	217	175	134	179	207	158	201
19		224	184	221	224	175	219	181	140	190	214	164	212
20		231	182	232	230	181	230	187	146	201	220	170	215
CHANGE/PERIOD		6.17	5.07	7.98	6.29	4.88	8.48	5.81	4.45	8.28	6.40	5.04	8.39

TABLE 87. AVERAGE PROFIT PER COW AT THE MEDIUM LEVEL OF ALL ECONOMIC FACTORS PERIODS 1 TO 20: 40-COW HERD, HIGH-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		205	179	169	204	178	167	180	162	151	192	165	154
2		211	184	175	210	184	173	185	167	157	197	171	160
3		218	189	180	217	188	177	191	170	159	205	175	164
4		225	194	185	225	192	181	198	171	161	212	180	169
5		232	198	190	224	196	187	205	173	165	220	184	175
6		239	203	196	231	200	194	211	177	172	218	189	182
7		247	207	203	239	205	202	218	181	172	226	194	190
8		254	212	211	246	210	211	224	186	180	233	199	198
9		261	218	219	253	216	211	231	182	190	240	205	207
10		259	223	228	260	221	222	237	188	200	248	210	207
11		266	229	238	267	227	232	244	193	211	255	216	217
12		273	234	248	274	224	243	250	199	222	262	222	228
13		280	240	258	280	230	254	257	205	233	269	219	239
14		286	246	260	287	236	266	263	211	245	276	225	250
15		293	252	271	294	242	277	260	217	257	283	231	261
16		300	258	282	300	248	289	267	223	260	289	237	273
17		307	264	293	307	254	291	273	229	272	296	244	285
18		313	261	305	303	261	303	279	236	284	303	250	287
19		320	268	317	310	267	315	286	242	296	299	256	299
20		326	274	329	316	273	327	292	248	308	306	263	311
CHANGE/PERIOD		6.25	5.11	8.38	6.13	4.82	8.57	5.88	4.44	8.53	6.33	4.96	8.40

TABLE 88. AVERAGE PROFIT PER COW AT THE MEDIUM LEVEL OF ALL ECONOMIC FACTORS PERIODS 1 TO 20: 120-COW HERD, LOW-PRODUCTION LEVEL

	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
PERIOD	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		110	87	78	109	87	77	71	49	39	97	75	64
2		114	92	83	114	92	82	75	54	44	102	79	69
3		120	97	87	121	97	86	82	58	47	109	84	74
4		128	102	92	129	102	92	89	61	51	116	89	79
5		135	106	98	137	107	98	97	64	56	123	94	85
6		142	111	104	145	112	105	103	69	62	131	99	92
7		149	116	111	152	117	112	110	73	70	138	104	99
8		156	121	118	159	122	121	116	78	78	145	110	107
9		163	126	126	159	127	129	122	82	86	152	115	115
10		169	131	134	165	132	138	128	87	95	159	120	124
11		176	137	143	172	138	148	134	92	105	159	126	133
12		182	142	152	178	143	150	140	97	114	165	131	142
13		188	147	161	184	148	160	146	102	124	171	136	152
14		194	153	171	190	154	170	151	108	134	178	142	154
15		193	158	180	196	159	180	157	113	144	184	147	164
16		199	163	183	202	165	190	163	118	155	190	153	174
17		205	169	193	207	163	201	168	124	165	196	159	185
18		211	174	203	213	169	211	174	129	168	202	164	195
19		217	180	213	219	174	221	172	134	179	208	163	205
20		223	185	224	224	180	232	178	140	189	213	168	216
CHANGE/PERIOD		6.00	5.17	7.80	6.01	4.91	8.25	5.86	4.79	8.30	6.09	5.14	8.08

TABLE 89. AVERAGE PROFIT PER COW AT THE MEDIUM LEVEL OF ALL ECONOMIC FACTORS
PERIODS 1 TO 20: 120-COW HERD, MEDIUM-PRODUCTION LEVEL

PERIOD	COW SEL / SIRE SEL	1 / 1	1 / 2	1 / 3	2 / 1	2 / 2	2 / 3	3 / 1	3 / 2	3 / 3	4 / 1	4 / 2	4 / 3
1		207	190	180	209	185	174	178	154	143	196	171	160
2		212	195	185	214	190	179	176	159	148	201	176	166
3		219	193	183	221	194	184	182	163	152	208	181	170
4		226	197	188	229	199	189	189	165	155	216	186	176
5		233	202	193	237	203	195	196	167	159	223	191	182
6		240	206	200	245	208	202	203	171	166	231	196	188
7		247	211	206	244	213	209	209	176	174	238	201	196
8		255	216	214	251	218	218	216	180	175	237	206	204
9		262	221	222	258	223	227	222	178	184	245	211	212
10		268	227	231	265	229	237	228	183	193	252	217	222
11		275	232	240	271	234	238	235	188	203	258	222	231
12		274	238	250	278	240	249	241	194	214	265	228	233
13		280	243	259	284	246	259	247	199	224	272	234	243
14		287	249	270	291	244	270	253	205	235	278	240	254
15		293	255	272	297	249	281	259	211	246	285	246	265
16		299	260	282	303	255	292	265	216	257	291	243	275
17		306	266	293	310	261	303	263	222	260	298	249	287
18		312	272	304	316	267	314	269	228	272	304	255	298
19		318	278	315	322	273	316	275	234	283	311	261	309
20		325	276	326	328	279	328	281	240	294	317	267	311
CHANGE/PERIOD		6.11	5.01	7.92	6.27	4.85	8.41	5.79	4.42	8.21	6.35	5.05	8.31

TABLE 90. AVERAGE PROFIT PER COW AT THE MEDIUM LEVEL OF ALL ECONOMIC FACTORS PERIODS 1 TO 20: 120-COW HERD, HIGH-PRODUCTION LEVEL

PERIOD	COW SEL	1	1	1	2	2	2	3	3	3	4	4	4
	SIRE SEL	1	2	3	1	2	3	1	2	3	1	2	3
1		301	274	265	303	277	266	275	257	246	290	263	253
2		307	280	270	308	282	271	280	263	252	296	269	258
3		313	285	275	315	286	276	286	266	255	303	274	263
4		320	289	280	323	290	280	293	267	256	311	278	268
5		327	293	285	322	294	285	300	268	260	318	283	274
6		335	298	291	329	298	292	306	272	267	316	288	280
7		342	303	298	337	303	300	313	276	267	324	292	288
8		349	308	306	344	308	309	319	281	275	331	298	296
9		356	313	314	351	314	318	326	277	285	338	303	305
10		354	318	323	358	319	319	332	283	295	346	308	314
11		361	324	333	365	325	330	339	288	305	353	314	315
12		368	329	343	371	322	340	345	294	317	360	320	326
13		375	335	353	378	328	352	351	300	328	367	326	337
14		381	341	355	385	334	363	358	306	340	374	323	348
15		388	347	366	391	340	375	355	312	351	380	329	359
16		395	353	377	398	346	387	362	318	354	387	335	371
17		401	359	388	405	352	399	368	324	366	394	342	383
18		408	356	400	401	358	400	374	330	378	401	348	395
19		415	362	411	407	365	412	381	337	390	397	354	396
20		421	369	423	414	371	424	387	343	403	404	361	408
CHANGE/PERIOD		6.22	5.07	8.34	6.10	4.78	8.58	5.86	4.42	8.47	6.30	4.96	8.45